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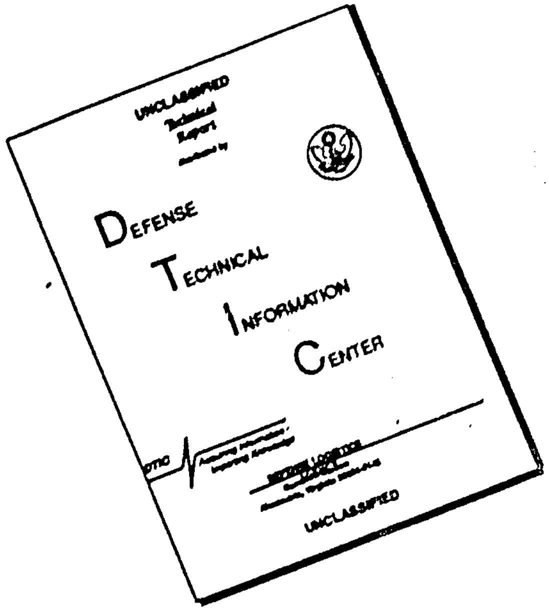

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SPRINGFIELD ARMORY

SPRINGFIELD, MASSACHUSETTS

RESEARCH AND DEVELOPMENT

Report: SA-TR19-1507

Date: 4 January 1962

Report Title: Properties and Methods of Nondestructive Testing of Bolts for 7.62mm M14 Rifles

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Industrial Production Engineering project

OMS Code: 4010.25.0005.2.01

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ABSTRACT

Studies were made to develop adequate inspection methods of evaluating properties of material used in the fabrication of the 7.62mm M14 bolts, and to determine the feasibility of using the developed method for final and in-process inspection. These studies included (1) investigation of bolt malfunction, (2) nondestructive tests re magnetic permeability comparisons, measurements of basic magnetic properties, oscilloscope wave form pattern studies, hardness investigations, (3) bolt segregation tests, (4) simulated impact tests, and (5) application to final and in-process inspection. A test method combining Rockwell C surface hardness, magnetic permeability readings, and oscilloscope wave form patterns was developed to evaluate properties of material used in the 7.62mm M14 bolt. The combination test method was found to be too complicated to specify as a final or in-process inspection method. A magnetic comparison method similar to that employed in the segregation program could be used as a means to determine uniformity of components within individual heat lots. Procedures are discussed and results given. It was recommended that the investigative program be continued.

CONTENTS

TABLES AND ILLUSTRATIONS

SUBJECT

Nondestructive Test Investigation of 7.62mm M14 Bolts.

PURPOSE

This investigation was conducted to develop adequate inspection methods for evaluation of material properties of bolts impounded because of serious weapon malfunctions, and to determine the feasibility of the developed method for final and in-process inspection of bolts to control quality.

SCOPE

A summary of the following investigations conducted by Research and Materials Laboratories, Springfield Armory, is given.

1. Investigations of Bolt Malfunction at Fort Benning and at "Code HG" Plant.

2. Nondestructive Test Studies.

   a. Magnetic Permeability Comparisons

   b. Measurements of Basic Magnetic Properties

   c. Oscilloscope Wave Form Pattern Studies

   d. Hardness Investigations

3. Bolt Segregation Tests.

4. Simulated Impact Tests.

5. Application to Final and In-Process Inspection.

CONCLUSIONS

1. A test method combining Rockwell C surface hardness, magnetic permeability readings and oscilloscope wave form patterns was developed to evaluate material properties of bolts impounded at Raritan Arsenal. A total of 33,808 bolts was inspected, with 26,848 of these reassembled into weapons.

2. The combination test method is too complicated to specify as a final or in-process inspection method. Engineers experienced with the segregation program and cognizant of wave pattern differences and resultant bolt material properties could employ the method, but the test is not sufficiently refined to specify limits and procedures to be incorporated in a drawing or specification for general inspection.

CONCLUSIONS - Continued

3. A magnetic comparison method similar to that employed in the segregation program could be used by contractors as a means to determine uniformity of components within individual heat lots, but not as a final or in-process inspection. Magnetic data gathered in conjunction with destructive examinations would be helpful in controlling process variables.

4. Magnetic nondestructive tests in themselves did not correlate directly with bolt material properties. Each magnetic investigation initially appeared to offer good correlation but was found in later studies to be influenced by different heat-treat practices and procedures used by contractors. Magnetic permeability tended to increase with increasing percentages of free ferrite in the core and to decrease with higher core hardness; it was shown to be affected also by surface hardness and tempering time and temperature to a great extent. Retentivity and coercive force measurements indicated correlation with core hardness within individual heats of bolts but were shown to be more affected by tempering temperature than by core hardness. Distortion in the negative portion of wave form patterns correlated well with high core hardness when bolts were not highly tempered or retempered.

5. Simulated impact tests at ambient and cold temperatures indicated that bolts with high core hardness fractured with the least number of impact blows and at the lowest heights for most part; those within specification and those with higher percentages of ferrite in the core exhibited the best impact properties. The presence of free ferrite, however, makes the core susceptible to fatigue failure.

RECOMMENDATIONS

It is recommended that:

1. A study be continued by Research and Materials Laboratories to determine the effectiveness of Rockwell C and D hardness measurements for estimation of bolt lug area core hardness (method has proved reliable to date on similar receiver studies).

2. Destructive examinations be continued at this time as in-process control of bolt quality.

3. Contractors be urged to use the magnetic permeability test to control heat-treating practices.

I. Introduction

This program arose as a result of an evaluation made on the metallurgical characteristics of M14 bolts and receivers involved in failures at Fort Benning, and from material currently supplied by all contractors for these items. This evaluation was requested at an M14 Task Group meeting held at Springfield Armory 28 December 1960 to determine the cause of four serious malfunctions of the M14 rifle reported by Fort Benning on 15 December 1960. During the investigation of the Fort Benning malfunctions, a "Code HG" receiver fractured on firing the first proof round. Metallurgical reports given at the meeting indicated that two major factors were immediately apparent: the use of improper receiver material and inadequate heat-treatment of bolts. Separate studies were conducted on many phases of the problem including ammunition, design, manufacturing and inspection procedures. In addition, malfunctions necassitated the requirement for nondestructive methods to test components insuring a high degree of confidence in the weapon and its component parts. Springfield Armory Report SA-TR19-1506 dated 7 November 1961 summarizes results of nondestructive test investigations conducted on M14 receivers; this report details the test studies made on M14 bolts.

Subsequent investigations on production bolts and observation of process methods employed by contractors indicated a most complex problem. Both gas and liquid carburizing methods were used in manufacture. Variations in equipment and heat-treating practices at different plants plus variations introduced into components in an attempt to salvage otherwise rejected parts due to skipped operations, distortion, and inadequate heat-treatment resulted in extreme variations in material properties. Process variables included wide differences in carburizing time and temperature, carburizing medium, and carbon potential resulting in different case depths, structure and hardness; type and speed of quenching oil together with different temperature, circulation, and degree of agitation; choice of tempering time and temperature to meet hardness requirement.

Establishment of acceptance criteria was extremely difficult because the number of failures had been small and actual conditions producing failures were not known. Bolts had not only variations in structure, differences in case and core hardnesses, and depth of case but also machining deficiencies, poor surfaces, lack of fillets, and other stress raisers. Probability was high that failures only occurred when some combination of conditions existed in the component.

I. Introduction - Continued

For clarification of acceptance criteria, bolt specification requirements were reviewed and additional requirements of core structure and core hardness imposed. Requirements which formed the basis for nondestructive tests were as follows:

Material:	8620H Resulphurized Steel (Carburized)
Case Hardness:	Rc 54-59
Core Hardness:	Rc 35-42
Case Depth:	.015-.020 inch
Temper Temperature:	425°F (max)
Core Structure:	10% Free Ferrite (max)

II. Investigations, Bolt Malfunctions at Ft. Benning and at "Code HG" Plant

A. Procedure

The following bolts of 8620H steel composition which failed were subjected to visual and magnetic particle inspection, dimensional analysis, and metallographic examinations:

Malfunctions at Ft. Benning

Rifles 19453, 19478, 19391 from "Code WH"
Rifle 19656 from Springfield Armory

Malfunction at Code HG" plant

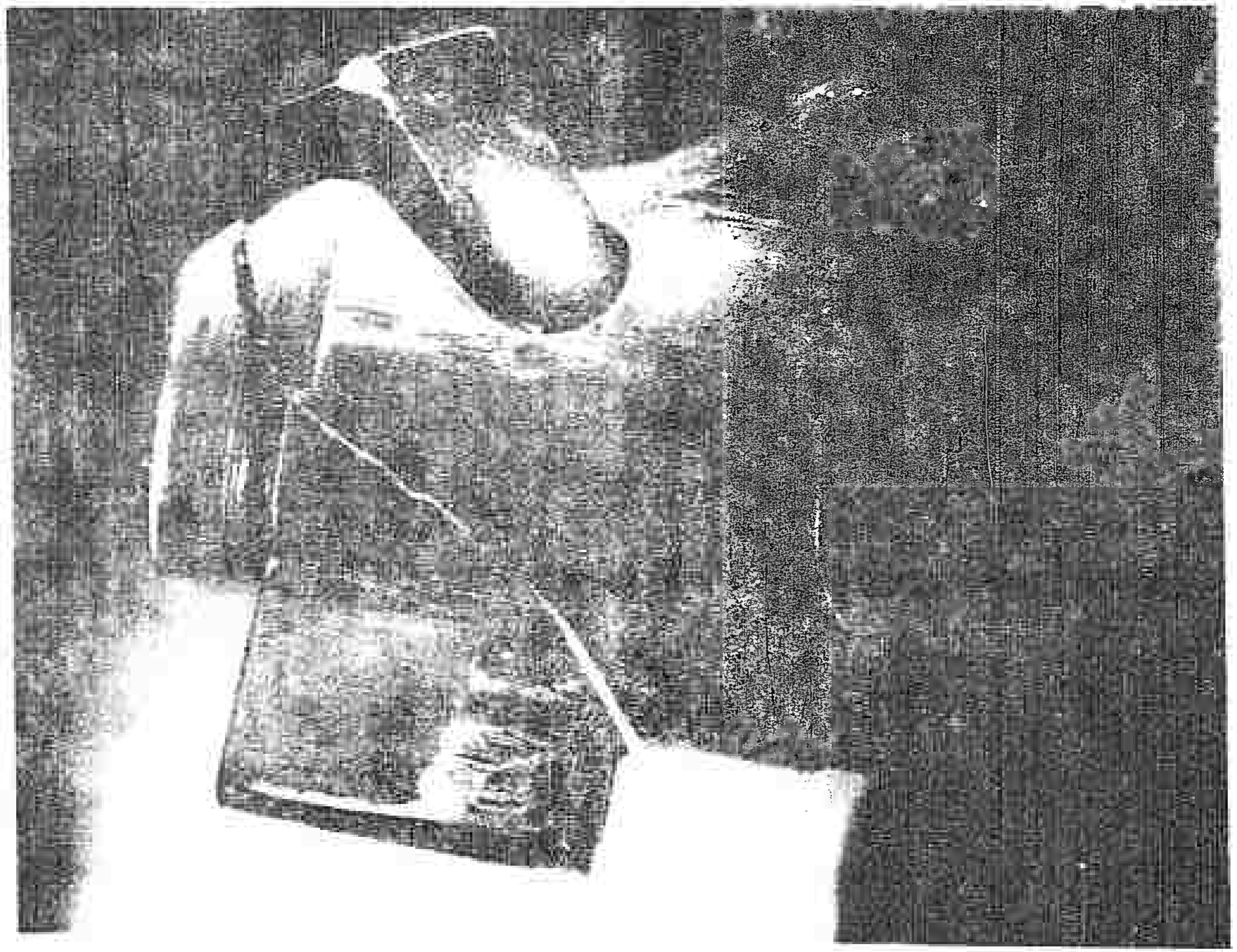
Rifle 73293 from "Code HG"

B. Results

1. Visual and Magnetic Particle Inspection

a. Bolt, Rifle 19453

The right lug was sheared off completely. The origin of the fracture appeared to be at the rear radius of the lug. Cracking also initiated at the rear radius of the left lug extending diagonally into the head and terminating at the cartridge seat area (Figures 1 and 2). Fracture (Figure 3) initiated in the locking lug radius and progressed by fatigue to a depth of 0.060 to 0.100 inch when catastrophic failure occurred.

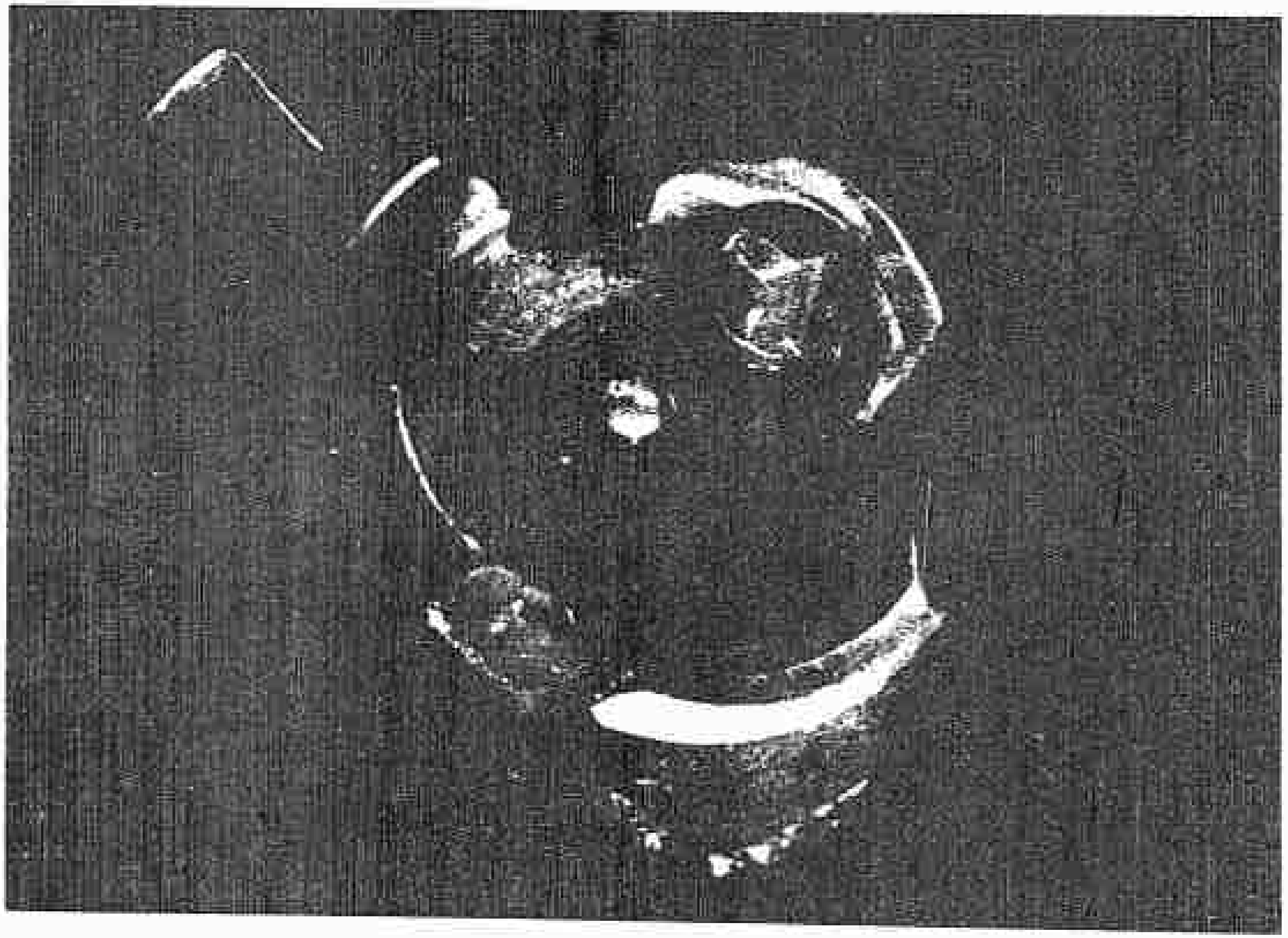


Neg: 19-058-1391/ORD-60 SPRINGFIELD ARMORY - ORDNANCE CORPS 15 Dec 1960

FRACTURED BOLT HEAD

Rifle, 7.62mm, M14 - "Code WH", No. 19453

Figure 1



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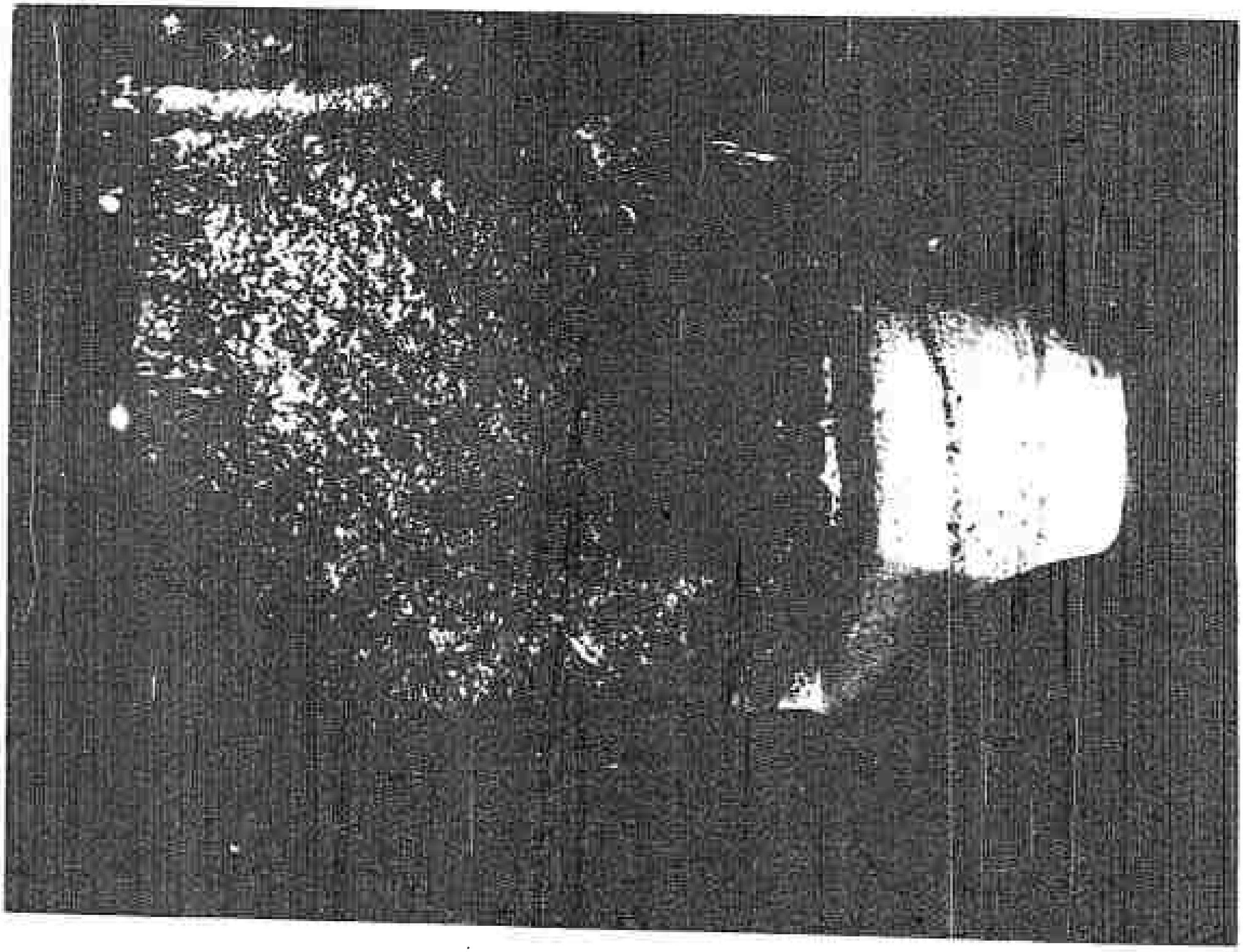
SPRINGFIELD ARMORY - ORDNANCE CORPS
DAMAGED BOLT FACE
Rifle, 7.62mm, M14 - "Code WH", No. 19453
Figure 2

15 Dec 1960



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SPRINGFIELD ARMORY - ORDNANCE CORPS

15 Dec 1960

FRACTURED BOLT

Showing fracture surface of broken right locking lug

Rifle, 7.62mm, M14 - "Code WH", No.19453

Figure 3

B. Results - Continued

b. Bolt, Rifle 19478

Excessive wear was noted at the bottom front face of the left-hand lug. Crack indications were observed across half the rear fillet of the right-hand lug.

c. Bolt, Rifle 19391

The left-hand lug was almost completely sheared. Magnetic particle indications of two parallel cracks extended across the radius of the right-hand lug with one extending around the corners.

d. Bolt, Rifle 19656

A triangular section approximately 7/8-inch long was broken off at the base of the ejector pin hole. Magnetic particle tests indicated cracks in the fillets of both lugs. Considerable wear and indentation were present on the rear face of the left-hand locking lug.

e. Bolt, Rifle 73293

Magnetic particle inspection revealed indications of cracks along the body radius of the left-hand lug extending to the chamfered corner. The bottom of the right-hand lug displayed abnormal peening from contact with the receiver lug. Indentation at the face of the left-hand locking lug was quite severe for firing one proof round.

2. Dimensional Analysis

a. Bolt, Rifle 19453

A dimensional check in the location of the locking lug surfaces indicated a misalignment of 0.001 inch over the permissible 0.002 inch. The fillet at the base of the left-hand lug was 0.006 inch. This is below the specified 0.020-0.010 inch.

b. Bolts, Rifles 19478 and 19391

No dimensional checks were made.

c. Bolt, Rifle 19656

Bolt had the forward edges of the locking surfaces approximately 0.003 inch forward of the drawing requirements and the rear edges misaligned by 0.0025 inch.

2. Dimensional Analysis - Continued

d. Bolt, Rifle 73293

No dimensional check was made.

3. Metallographic Examination

Sections cut from the locking lugs were used for all metallographic specimens prepared from this group. Specimens were examined in the as-polished condition to determine cleanliness of steel and subsequently in the etched condition. The material in all the bolts appeared to be reasonably clean and free from objectionable inclusions, except for bolt 19656 which exhibited a heavy group of aluminum oxide inclusions. Tabulation of results obtained in metallurgical examinations are shown in Appendix A, Section 1.

a. Bolts, Rifles 19453, 19478, and 19391

These failed bolts contained approximately 50 per cent proeutectoid ferrite in the core (Figure 4). Because of its occurrence with a microstructure containing a high percentage of martensite and low-temperature transformation products, it was concluded that these bolts had been held below, and quenched from, slightly below 1520°F, the AC_3 transformation temperature for 8620 steel. This conclusion was substantiated when Task Force groups reported that "Code WH" procedure involved carburizing followed by slow cooling, and reheating to 1475°F-1500°F for the final quenching operation.

b. Bolt, Rifle 19656

The microstructure appeared to be normal, i.e., characteristic of that obtained by Springfield Armory production heat-treating procedures (Figure 5). The core displayed small amounts of proeutectoid ferrite, 5 per cent maximum, with the remainder about evenly divided between upper and lower transformation products.

c. Bolt, Rifle 73293

The microstructure in the core consisted mainly of martensite and lower bainite with a small percentage of upper bainite and traces of free ferrite. The case contained approximately 20 per cent retained austenite to depths of 0.004 inch. Photomicrographs of the case and core together with the crack observed in the rear fillet of the left hand lug are shown in Figure 6.

FIGURE 4

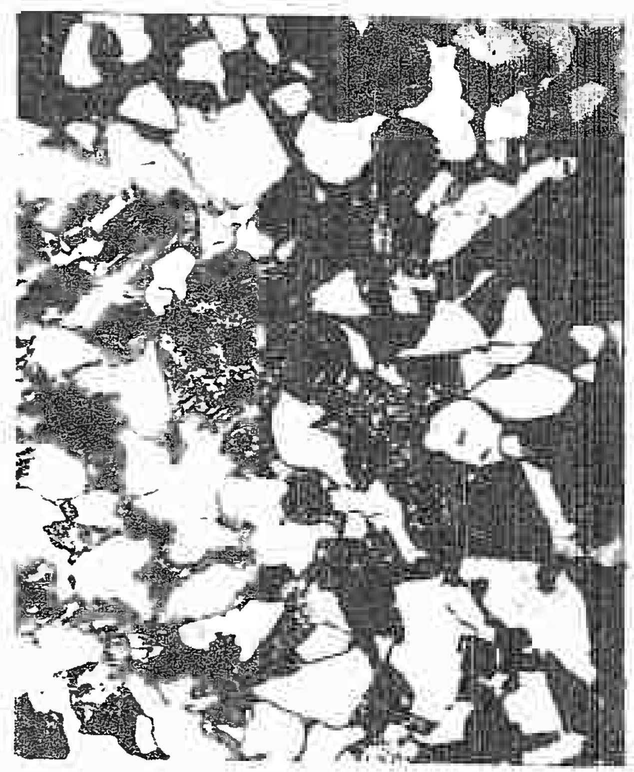
PHOTOMICROGRAPHS DISPLAYING CASE AND CORE MICROSTRUCTURES

OF

FRACTURED "CODE "WH" M14 BOLT - RIFLE 19453

CASE

CORE

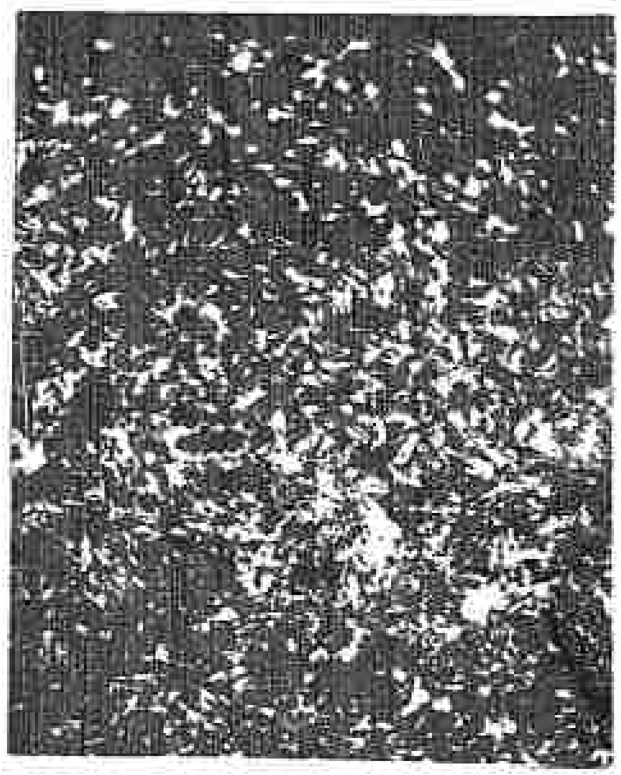


Etchant: Nital Mag: 1000X

FIGURE 5

PHOTOMICROGRAPHS DISPLAYING CASE AND CORE MICROSTRUCTURES
OF
SPRINGFIELD ARMORY M14 BOLT - RIFLE 19656

CASE



CORE

Etchant: Nital Mag: 1000X

FIGURE 6

PHOTOMICROGRAPHS DISPLAYING CRACK, CASE AND CORE MICROSTRUCTURES

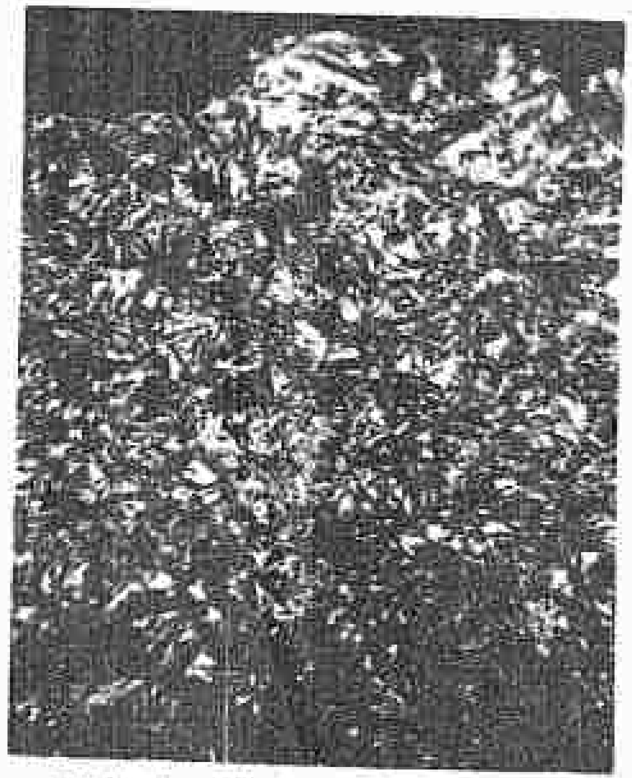
OF

"CODE HG" M14 BOLT - RIFLE 73293

CRACK

Not Etched Mag: 1000X

CASE



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CORE

Etchant: Nital Mag: 1000X

III. Investigations: Nondestructive Magnetic Test Studies

Many varied nondestructive magnetic test studies were conducted at the Armory in an attempt to develop adequate test methods for bolt inspection. In connection with tests, a great number of bolts were sectioned and metallurgically examined to determine structure, hardness, and case depth data. Each magnetic investigation required additional destructive examinations because once sectioned, the bolts with then known properties could not be used. The bolt section used for metallurgical examinations in all studies is shown in Figure 7. Watertown Arsenal personnel assisted the Armory in metallurgical examinations of bolts.

A. Magnetic Permeability Comparisons

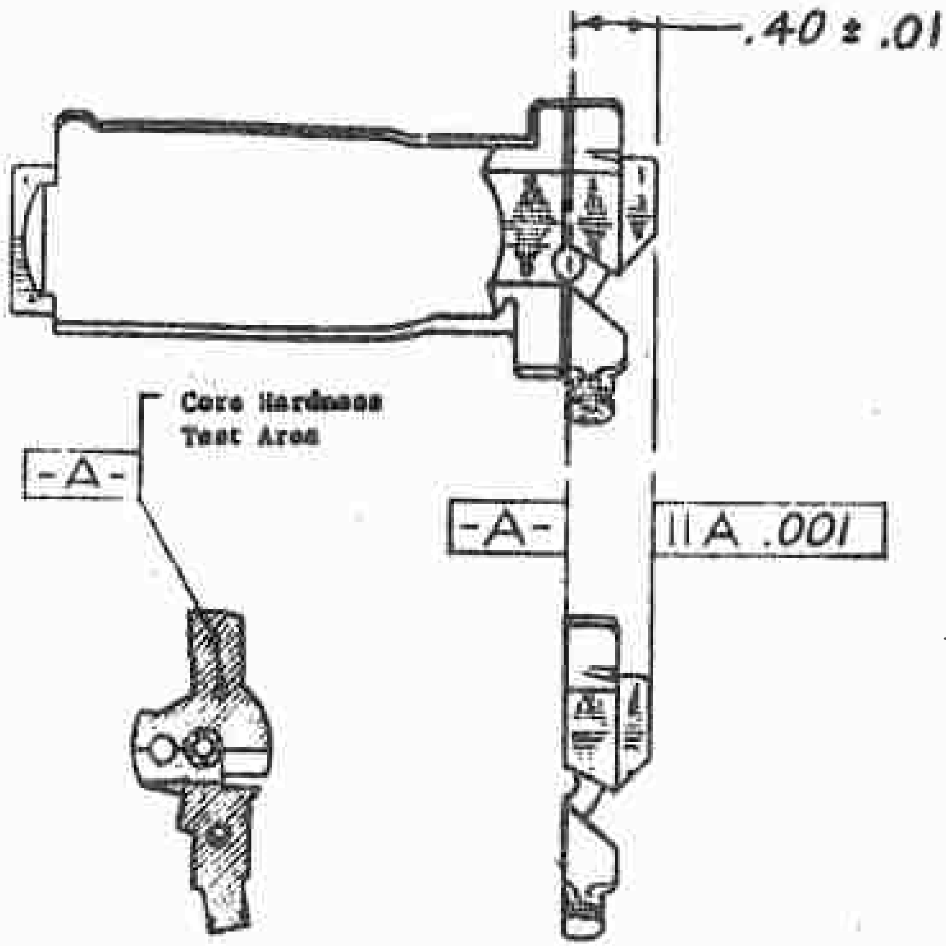
1. Equipment Employed

In the initial work, magnetic comparator type equipment was employed. The equipment is shown in Figure 8. Basically, it contained a 60 cps generator, a pair of similar coils, an amplifier, and filter and detector circuits for indicating the resultant coil output voltage. Each of the similar coil units contained a primary and a secondary winding. The primary winding of each coil applied an a.c. magnetizing field to the sample placed in the coil. The secondary windings were connected in series opposition so that only the difference-voltage between the two secondaries was measured by the indicator circuit. When like samples with identical magnetic properties are placed within the coils, the induced voltage in each secondary winding is equal and the resultant output voltage is zero. In the actual test, a reference bolt was placed in one coil where it remained throughout the test. Bolts being compared were then inserted in the other coil.

2. Results

Bolts heat-treated by gas and liquid carburizing processes were tested. Bolts selected for tests were taken from lots known to contain varying percentage of free ferrite in the core, others with high core hardness, and some within specification requirements. Four magnetic comparison variations were studied to determine which one revealed widest differences with bolts examined. Wave forms were noted in order to study phase shifts and presence of harmonics. Filter networks made it possible to measure the resultant secondary output in terms of the fundamental frequency only (60 cps), the third harmonic only (180 cps), the fundamental plus all harmonics, and all harmonics with the fundamental filtered out.

Figure 7



Test Specimen for Case Depth, Free Ferrite, and Core Hardness Tests

Bolts shall be sectioned as indicated above. Surfaces shall be ground (fine grind) parallel as shown. Surface A shall be prepared for tests in accordance with SA STD-104, Test Method No. 102 (Steps 3 (a) and 3 (b) not required above procedure).

(Extreme care should be exercised in cutting bolt so as not to burn, temper, or change microstructure of any surface.)

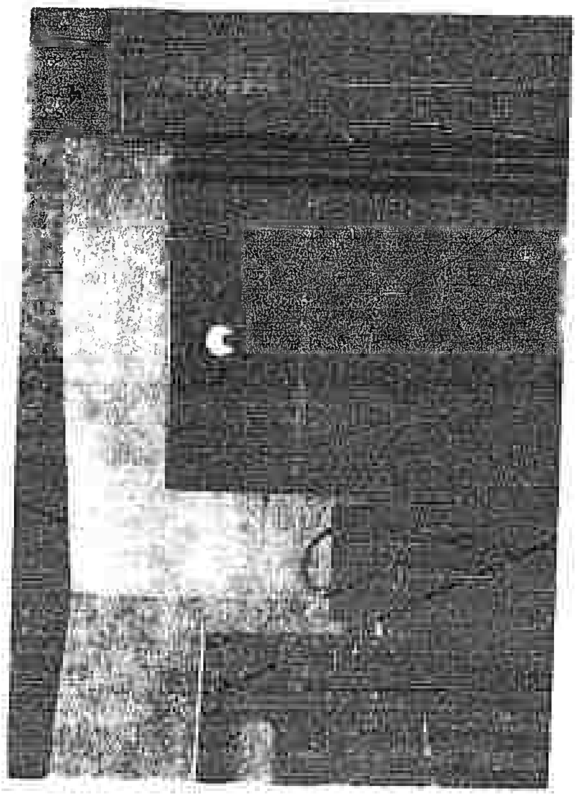


FIGURE 8 MAGNETIC ANALYSIS PRODUCTION COMPARATOR EQUIPMENT

A. Magnetic Permeability Comparisons - Continued

Widest magneti: differences were noted employing the fundamental wave pattern only (60 cps) and the fundamental plus all harmonics. Metallurgical examinations revealed wide variation in core properties. Magnetic readings indicated a general grouping with properties, but with unaccountable differences within each group. Readings primarily representing a permeability measurement appeared to show that permeability increased with increasing percentages of free ferrite in the core and decreased with higher core hardness; however, too many exceptions were noted to assume any correlation.

B. Measurements of Basic Magnetic Properties

Because permeability appeared to offer insufficient correlation with core hardness, studies of other measurable magnetic properties, such as retentivity, coercive force and residual flux density were undertaken.

1. Retentivity Measurements

a. Equipment Employed

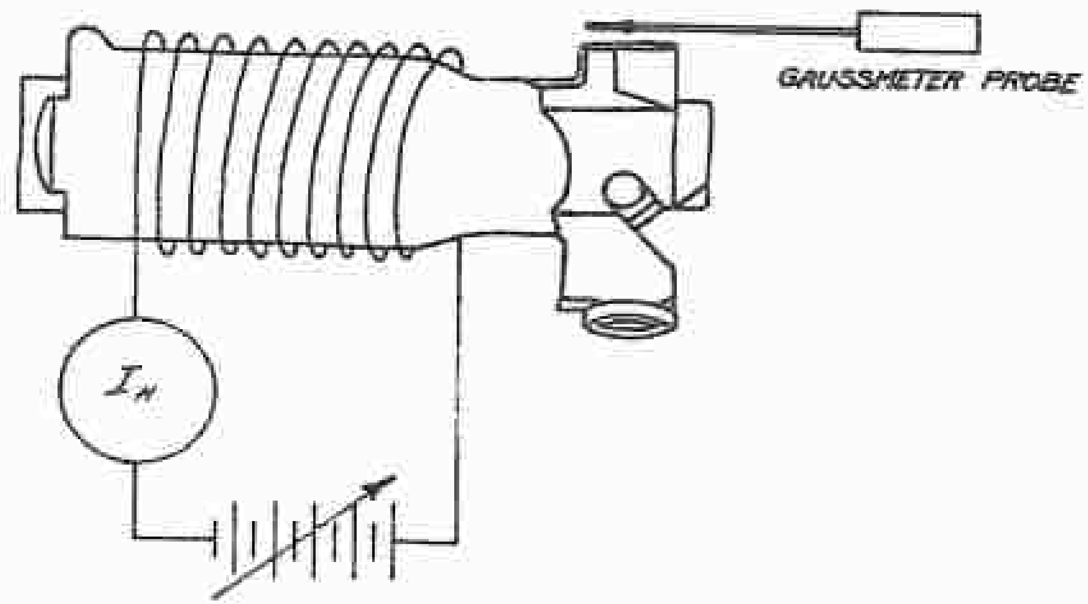
Retentivity, the flux density remaining after a magnetizing current sufficient to cause saturation has been applied and reduced to zero, was measured with laboratory equipment comprising a d.c. power supply, a magnetizing coil and a gaussmeter. Arrangement is shown in Figure 9. In addition, the opposing current required to bring the retentivity to zero was recorded. Measurements were extremely sensitive to probe position.

b. Results

A plot of opposing current ($-I_H$) versus Rockwell C core hardness data on bolts from "Code WH" heat-treated as a group is shown in Figure 10.

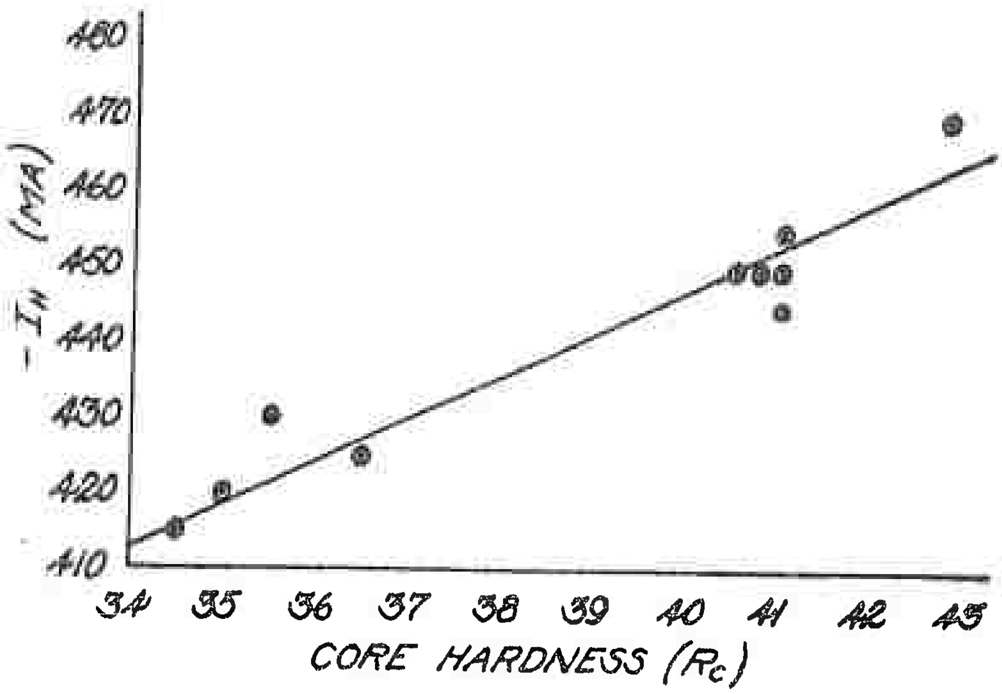
Graph indicates good correlation of ($-I_H$) with averaged core hardness on this group of bolts. Unfortunately, however, when bolts from various heat-treat processes were tested and metallurgically examined, data did not plot linearly. Numerous results did not fall on the curve. Compilation of opposing current data hardness measurements, and microstructure examinations are shown in Appendix, Section 2. Data show that very hard bolts (Rc44-46) which had been retempered gave ($-I_H$) values of 350-370 milliamperes. Bolts which were not retempered and had hardness (Rc 37-40) measured 400-410 ma. Another group retempered at 530°F with core hardness (Rc 41-43) had ($-I_H$) data in the vicinity of 265 ma. It was thus concluded that the measurement was more affected by tempering temperature than core hardness.

FIGURE 9 ARRANGEMENT FOR RETENTIVITY MEASUREMENT



ARRANGEMENT for RETENTIVITY MEASUREMENTS

FIGURE 10 OPPOSING CURRENT VERSUS CORE HARDNESS ON "CODE WH" BOLTS



RETENTIVITY vs CORE HARDNESS MEASUREMENTS

B. Measurements of Basic Magnetic Properties - Continued

2. A. C. Hysteresis Loop Measurements

a. Equipment Employed

A. C. hysteresis loop measurements were next made in an effort to correlate core hardness. A 60 cps generator was used to induce an A. C. field in a u-shaped, high permeability, laminated core. A secondary winding encircled the bolt. The bolt was placed against the pole faces of the laminated core; thus the magnetic circuit was completed. By means of a phase shifting network, a hysteresis loop was displayed on an oscilloscope. The experimental arrangement is shown in Figure 11.

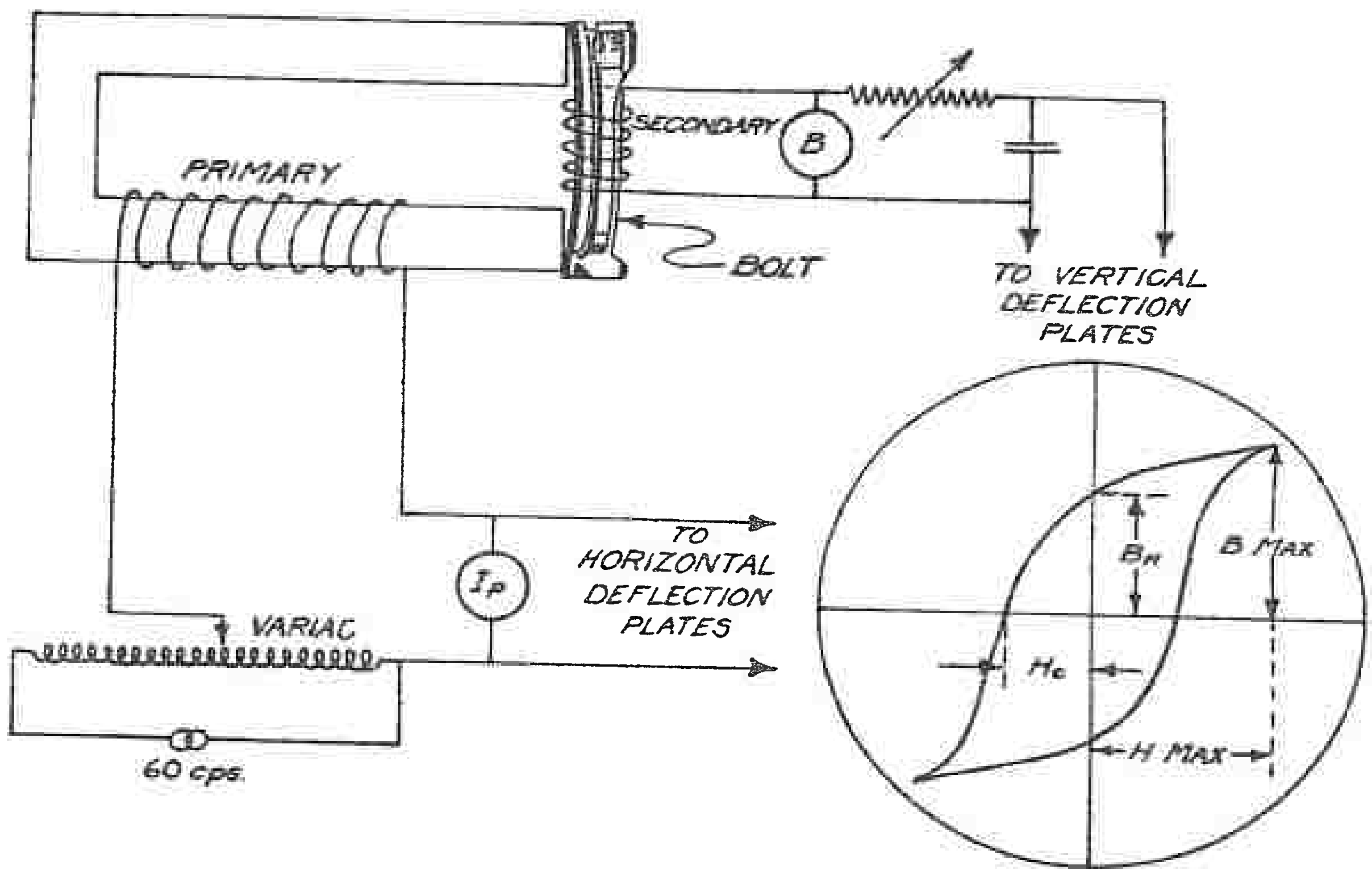
b. Procedure

Coercive force (H_C) and residual flux density (B_R) measurements were recorded on nearly 200 bolts; first, at saturation flux density; then, at a constant flux density below saturation. The greatest sensitivity was indicated with the use of the latter. Before destructively examining any of these bolts, magnetic readings were recorded with the use of a previous magnetic comparator setup in an attempt to gather as much data on this group of bolts as possible.

c. Results

Coercive force, residual flux density, and core hardness data obtained on eighteen "Code WH" bolts are listed in Table 1. Additional metallurgical data compiled on these bolts are shown in the Appendix, Section 3.

FIGURE 11 EXPERIMENTAL ARRANGEMENT FOR A.C. HYSTERESIS LOOP MEASUREMENTS



EXPERIMENTAL ARRANGEMENT for A.C. HYSTERESIS LOOP MEASUREMENTS

B. Measurements of Basic Magnetic Properties - Continued

TABLE 1

Coercive Force, Residual Flux Density, and Core Hardness Data on "Code WH" Bolts

Bolt Identity	Constant Magnetizing Current above Saturation		Constant Flux Density Below Saturation		Range Core Hardness
	H_c x 2	B_R x 2	H_c x 2	B_R x 2	Rc
66118A -8	3.75	5.0	3.55	8.9	41.5-43.5
-18	3.75	5.4	3.35	8.75	42-43
-9	3.7	5.4	3.35	8.8	42.5-44
-12	3.8	5.25	3.45	8.8	41.5
-11	3.8	5.2	3.4	8.9	40.5-42.5
-16	3.8	5.4	3.35	8.6	40-42
-15	3.7	5.3	3.3	8.8	40.5-42.5
-13	3.75	5.4	3.3	8.7	39.5-42
-10	3.7	5.6	3.2	8.7	40-42
-5	3.7	5.5	3.2	8.75	40-42
-3	3.8	5.55	3.3	8.7	38-40.5
-1	3.8	5.45	3.2	8.5	38-41
-4	3.7	5.3	3.3	8.8	36.5-38
-17	3.7	5.4	3.2	8.7	34.5-39
-2	3.7	5.3	3.2	8.6	32-40
-14	3.7	5.5	3.1	8.6	35-37.5
-7	3.8	5.2	3.15	8.7	32-39.5
-6	3.75	5.6	3.1	8.7	34-37

B. Measurements of Basic Magnetic Properties - Continued

In total approximately 60 bolts were sectioned and the metallurgical results most carefully compared with the collected magnetic data. Promising correlation of coercive force versus core hardness on this group of bolts was indicated with data obtained at constant flux density below saturation. However, as with retentivity studies, in measurements made on retempered bolts, it was shown that coercive force was more affected by tempering temperature than core hardness. Table shows coercive force and hardness data on Armory bolts from heat lot CA3 tempered at 400°F, and "Code HG" bolts identified CA05 retempered at 530°F.

TABLE 2

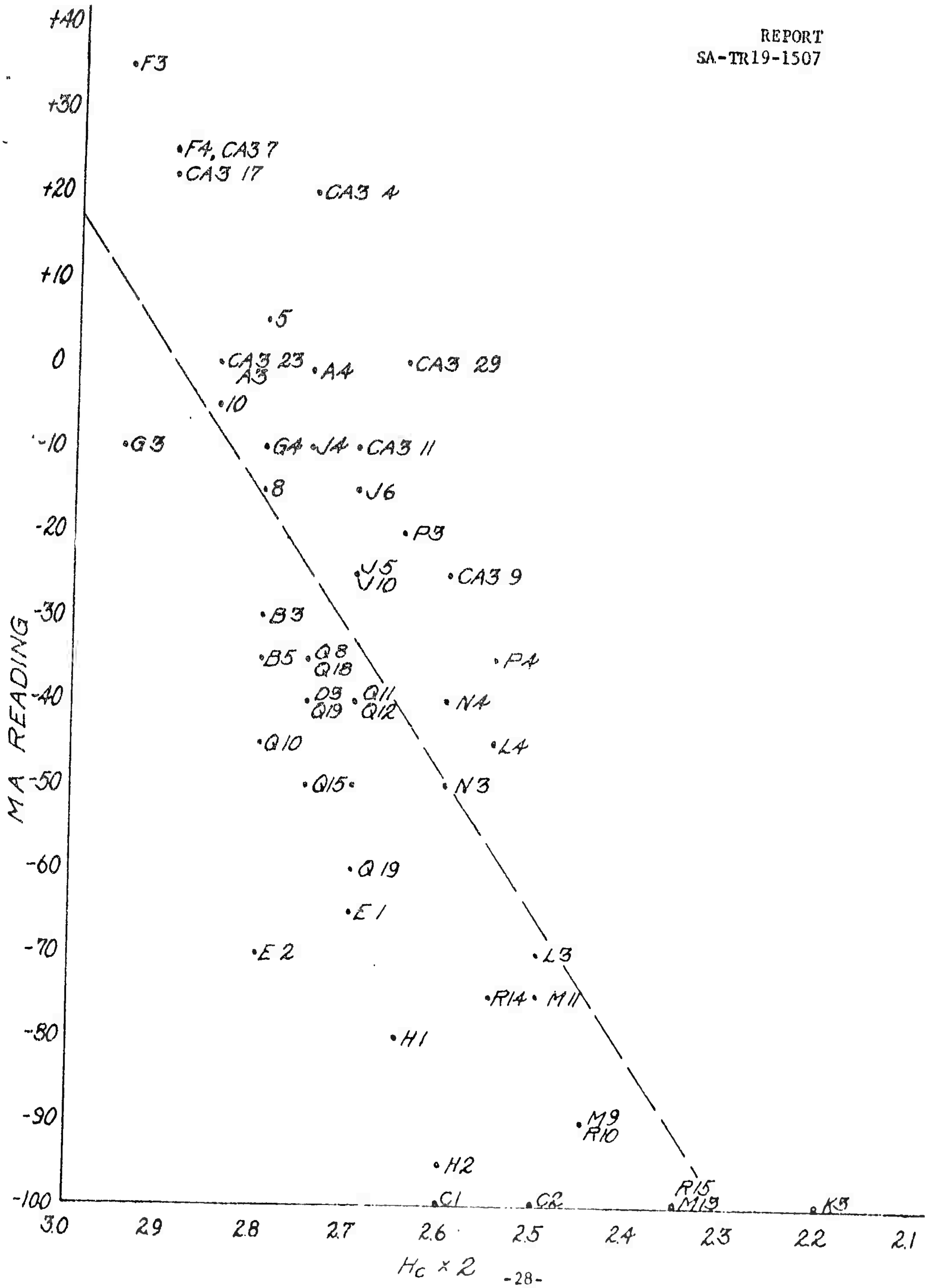
Hysteresis Loop and Hardness Data on Bolts Normally Tempered and Retempered at High Temperature

Bolt Identity		Constant I_H Above Saturation		Constant Flux Density Below Saturation		Range Core Hardness
		H_C x 2	B_R x 2	H_C x 2	B_R x 2	Rc
CA3	-4	4.0	5.9	2.7	8.0	41.5-42
	-9	3.9	6.0	2.6	7.8	37-41
	-25	3.9	5.9	2.7	7.8	39-40
CA05	-1	2.9	5.9	1.7		42-43
	2	2.8	5.95	1.65		43-44
	3	2.9	5.9	1.7		44-45
	4	2.8	5.9	1.65		41-42

Previous studies appeared to show that coercive force increased with hardness; whereas, results of the present studies show that coercive force was more influenced by retempering at high temperatures than by core hardness. Bolts of higher core hardness had coercive force decrease when retempered.

A plot of coercive force versus magnetic comparator readings appeared significant (Figure 12). It was possible for a boundary line to be drawn on the data plot which divided for most part acceptable components from deficient ones. Bolts containing a high percentage of

FIGURE 12 PLOT OF COERCIVE FORCE VERSUS MAGNETIC COMPARATOR READINGS



B. Measurements of Basic Magnetic Properties - Continued

free ferrite were separated from those which had been highly tempered or retempered. Previous magnetic comparisons had not differentiated these conditions. A 100 per cent correlation was not obtained; however, a few gas-carburized bolts (P3 and P4) with comparatively low surface hardness and very high core hardness upset the correlation in that these plotted within a group of acceptable bolts. Metallurgical results comprising surface and core hardness, microstructure, and case depth measurements on bolts plotted are shown in Appendix, Section 4.

3. Hardness - Magnetic Permeability Investigation

The noted discrepency in correlation proved most important because greater concentration was now given to the surface hardness variable. Because flux density is at a maximum on the bolt surface and decreases in an exponential manner into the core, it seemed most reasonable to more carefully consider surface hardness when examining the magnetic data with respect to core hardness.

Table 3 indicates that magnetic readings were affected greatly by surface hardness. Rockwell C core hardness was essentially the same, surface hardness varied, and magnetic readings differed by approximately 85 points.

TABLE 3

Effect of Surface hardness on Magnetic Readings

Magnetic Reading	Surface Hardness Rc	Body Core Hardness Rc
+25	62	38.5, 39, 39, 42, 42
-31	58	38, 39.5, 39.5, 40, 41.5
-62	55.5	39.5, 40, 41, 42, 42.5

Table 4, however, likewise indicates that core hardness influences magnetic readings. Bolts of similar or identical surface hardness were selected and magnetic readings and core hardness were compared.

B. Measurements of Basic Magnetic Properties - Continued

TABLE 4

Effect of Core Hardness on Magnetic Readings

Magnetic Reading	Surface Hardness Rc	Body Core Hardness Rc
-3	56-56	43, 43, 43, 43.5, 44
-4	55-57	42.5, 43, 43, 44, 45
-20	55.5-57	37, 38.5, 39, 39, 39.5
-27	55-56	36, 39, 40, 40.5, 40.5
-42	56-56	36, 37, 38, 38, 39
-62	55-56	36, 36, 36, 37, 37.5

Magnetic and hardness data were next plotted and studied. A chart relating surface hardness, magnetic reading, and core hardness was developed. With surface hardness and magnetic reading known, it is possible to predict core hardness from this chart (Figure 13).

C. Wave Form Pattern Studies

At this point in the investigation 1800 bolts were received from Raritan Arsenal; these bolts required some type of segregation because of the urgent need for supplying the field.

Magnetic permeability and Rockwell C surface hardness measurements were recorded on all 1800 bolts. Twenty-five of these bolts were selected and a prediction of core hardness made. Twenty-four provided an accurate determination of core hardness within ± 1.5 points Rockwell C. The other was 5 points Rockwell C harder than predicted.

In the conducting of the magnetic permeability tests, similar characteristic wave form patterns were observed on the oscilloscope. Three basic patterns, with many variations of these, were apparent. Designated pattern 1 was an undistorted sine wave; pattern 2 had third harmonic distortion; and pattern 3 indicated severe distortion of the 60 cps fundamental on the negative portion of the display. Hardness measurements and microstructure examinations were made on bolts with above characteristic patterns. Table 5 lists hardness, magnetic reading, and pattern information gathered on 19 bolts. Other metallurgical data on these bolts, and additional magnetic and metallurgical investigations made in this study are compiled in Appendix, Section 5.

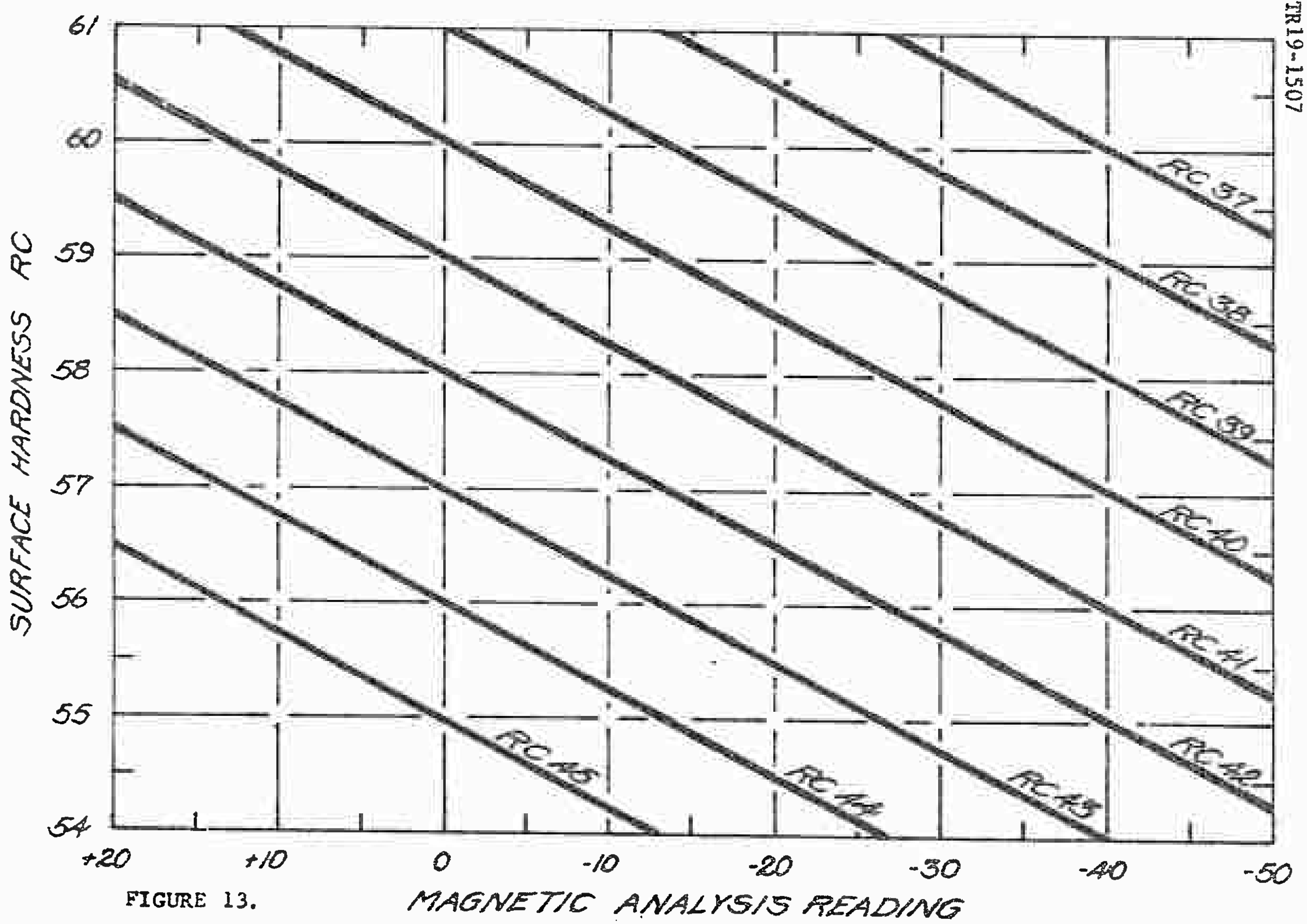


FIGURE 13.

CORE HARDNESS PREDICTION CHART BASED on ROCKWELL C HARDNESS MEASUREMENTS

C. Wave Form Pattern Studies - Continued

TABLE 5

Data on Bolts with Basic Wave Form Patterns

Bolt Identity	Magnetic Reading	Basic Wave For Pattern	Surface Hardness Rc	Body Core Hardness Rc	Lug Core Hardness Rc
67988	-15	1	57.5-58	38,38,39,39,39	39,39,39.5,40.5,42
69216	-18	1	59-59	39,39,39,40,41	37,39,40,40.5,41
77533	-32	1	58-59	36,36,36.5,37,37	37.5,38,38,40,40.5
78153	-50	1	57.5-59	36,36,36.5,37,37	36,37,38,40,40.5
75089	-92	1	54.5-56	37,37,37,37,39	37,38,39,39.5,42
69832	+20	2	59	39,40,40,42,43	42,42,43,43,43.5
76002	+12	2	61.5-62	38,39,39,41,42	36,36.5,37.5,38.5, 40
70825	0	2	55.5-56	36,38,38,38,40	36,37.5,38,38,42
70190	-2	2	58-58	39,39,39,40,41	40,40,42,42.5,42.5
68722	-24	2	58.5-59	36,36,37,38,39	37,37.5,38,40,40
71355	-27	2	57.5-58.5	37,38,38,39,41	38,39,39.5,40,41
73237	-33	2	58	36,37,37,39,40	35.5,35.5,35.5,36 37.5
77109	-36	2	57-58.5	36,37,37,40,40	35.5,36,36,36.5,37
70400	-10	3	57.5-58	41,44,45,45,45	43,45,45,45,46
69981	-12	3	57.5-58	42,43,45,45,45	44,44.5,45,45,45
74387	-14	3	56.5-57.5	42,43,43,43,44	43.5,43.5,44,44.5, 44.5
74823	-15	3	53.5-56	43,45,45,46,46	42.5,43.5,44,44,45
77188	-27	3	58.5-59	42,42,43,43,43	41,43.5,43.5,44,44
76924	-75	3	56.5	42,45,45,45,45	44,45,45,46,46

C. Wave Form Pattern Studies - Continued

Results show that basic patterns offer some correlation. Bolts with basic patterns 1 and 2 have core hardness within specification; bolts with pattern 3 consistently indicate high core hardness above specification requirements.

In order that pattern variations be studied further, approximately 150 oscillograms were taken of the differing degrees of distortion. The corresponding bolts were sectioned and metallurgically examined. Six obvious patterns and their variations were correlated with material properties. Patterns correlated are shown in Figure 14; metallurgical data are compiled in Appendix, Section 6.

D. Bolt Segregation Tests

1. Procedure

Based on results of all studies, a combination test method employing magnetic permeability readings, Rockwell C surface hardness measurements, and oscilloscope wave form patterns was used in bolt segregation. A Rockwell C hardness measurement was taken on the rear part of the bolt or on a lug area. The bolt was then subjected to magnetic test wherein amplitude and pattern were noted. The combination was evaluated and bolts were segregated into the following groups:

Group A - Core hardness Rc 35-42.5, core structure ferrite less than 10 per cent.

B - Core hardness Rc 42.5-45.

C - Surface hardness outside Rc Specification.

D - High temper or retemper.

E - Core hardness greater than Rc 45.

F - Core hardness less than Rc 35.

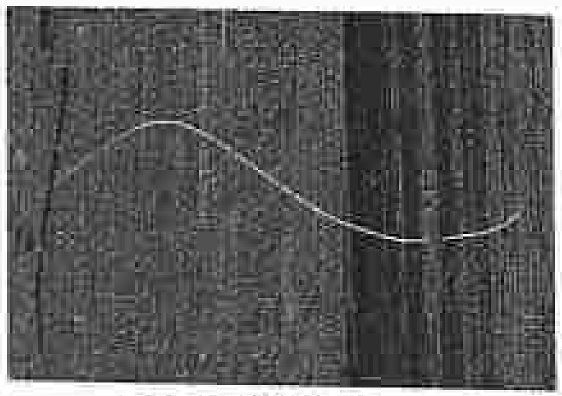
G - Core structure excess free ferrite.

H - Rejected other unfavorable conditions.

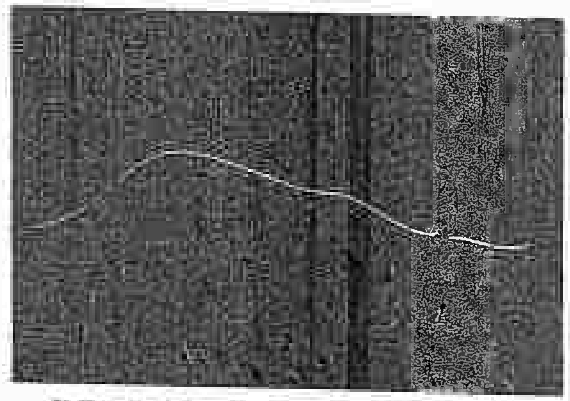
2. Results

A total of 33,808 bolts was inspected at Springfield Armory employing the combination test method. Segregation into each group was as follows:

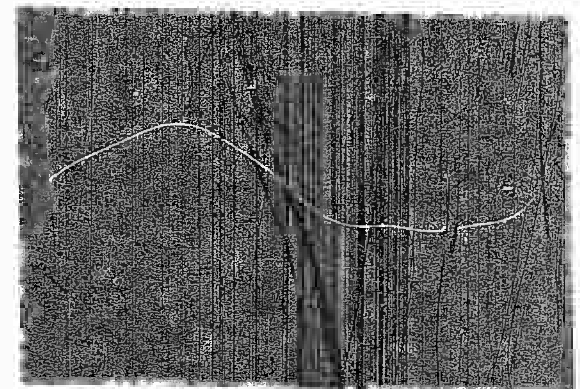
FIGURE 14 WAVE FORM PATTERNS CORRELATED WITH MATERIAL PROPERTIES



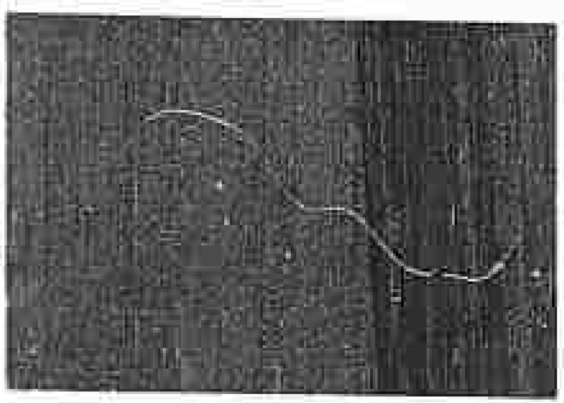
ACCEPTABLE



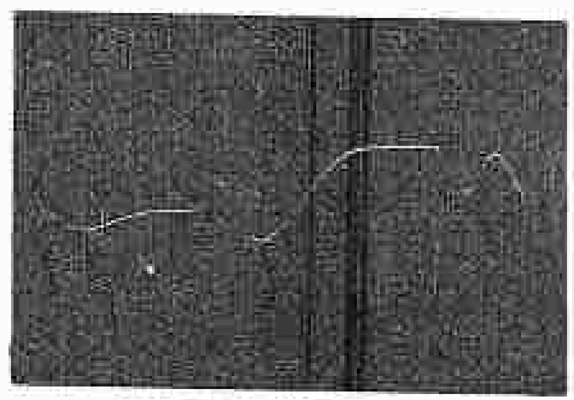
BORDERLINE ACCEPTABLE



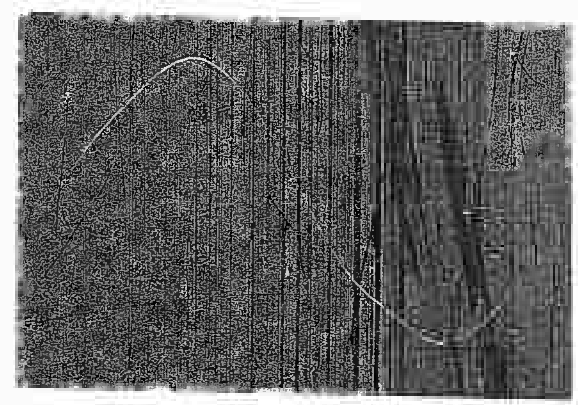
REJECTABLE
HIGH CORE HARDNESS



REJECTABLE
HIGH PERCENTAGE FERRITE



REJECTABLE
DECARBURIZED



HIGHLY TEMPERED
OR RETEMPERED

WAVE FORM PATTERNS CORRELATED WITH MATERIAL PROPERTIES

D. Bolt Segregation Tests - Continued

Group A	-	6,827
B	-	20,021
C	-	660
D	-	3,399
E	-	94
G	-	587
H	-	2,220
		33,808

Based on decision of higher authority, Groups A and B represented acceptable groups for reassembly into weapons. As such, 26,848 bolts were salvaged.

E. Simulated Impact Tests

1. Procedure

In an effort to evaluate various groups of bolts segregated by magnetic methods and to determine if correlation existed between component impact strength and its metallurgical properties, impact tests were conducted employing a Tinius Olsen Drop Tester. To this end a fixture was designed and fabricated to hold the bolts in a manner similar to that of the weapon receiver. The component rested vertically in the fixture on its rear locking lug faces. A cap held in place by locking pins rested on the front locking lug faces. Through a hole in the cap, a piston was inserted in contact with the bolt cartridge seat. Drop tests were conducted at ambient and cold temperatures from various fixed heights and increasing heights with 10- and 20-pound hammers. Bolts for tests were selected from evaluations made of surface hardness, magnetic reading and wave form pattern.

2. Results

Initial tests made with a 20-pound hammer and an impact force of 40 foot-pounds were inconclusive in that the test was considered too drastic. All bolts failed after a single or only a few blows.

Bolts with patterns characteristic of structures and core hardness within specification (Group A), those with core structures of varying percentage of ferrite (Group G), and those with core hardness higher than specification hardness (Group B) were next tested with an impact of 10-pound hammer at 3 foot height. Results in Appendix, Section 7 show that bolts of highest core hardness fractured with the least number of blows for most part. Bolts within specification and those with higher percentages of ferrite in the structure exhibited the best impact properties. From experience with initial failures, it was apparent that low core hardness and/or free ferrite in excess of 10 percent produced a weak component which will fail prematurely in fatigue.

E. Simulated Impact Tests - Continued

Highly tempered or retempered bolts, because of the large quantity found in segregation, were next studied. Tempering in itself is generally considered beneficial but for 8620H material it was found that bolts were approaching a "blue brittle range" with the temperatures used. Charpy impact tests had shown that impact strength dropped sharply on bolts that had been tempered at 530°F. Additional magnetic and simulated impact studies were attempted in order to evaluate acceptable conditions.

Because highly tempered and retempered magnetic patterns had large amplitudes with variations hard to detect, double exposure oscilloscope records were taken on bolts studied. The first exposure was taken with the bolt in its proper position within the coil; the second exposure was made with the bolt pulled out until the meter read zero. With this procedure, four basic patterns designated A1, B1, C1 and D1 were noted. Basic patterns are shown in Figure 15.

Simulated impact tests made on bolts with these various patterns employing an impact of 30 foot-pounds indicated that bolts with patterns A1 and B1 withstood the greater number of impact blows. Metallurgical results indicated that pattern A1 had fairly high percentages of free ferrite in the core (10 to 25%). Bolts with patterns C1 and D1 failed quickly (1-3 blows); corresponding core hardness was high. Impact test and metallurgical data are compiled in Appendix, Section 8.

Tests were also conducted at temperatures approaching -65°F. The fixture used to align bolts was incased in dry ice and acetone. Bolts were soaked in the bath before insertion in the fixture. The impact test machine was set so that after impact the hammer was raised an additional inch. Successive impacts were thus increasingly higher. Results (Appendix, Section 9) were quite similar to those obtained at ambient temperatures. Bolts with higher core hardness fractured for most part at the lowest heights; bolts with higher percentages of ferrite in the core fractured at the highest heights.

Although results indicated that bolts with high percentages of ferrite in the core gave best impact results, the presence of free ferrite makes the core susceptible to fatigue failure.

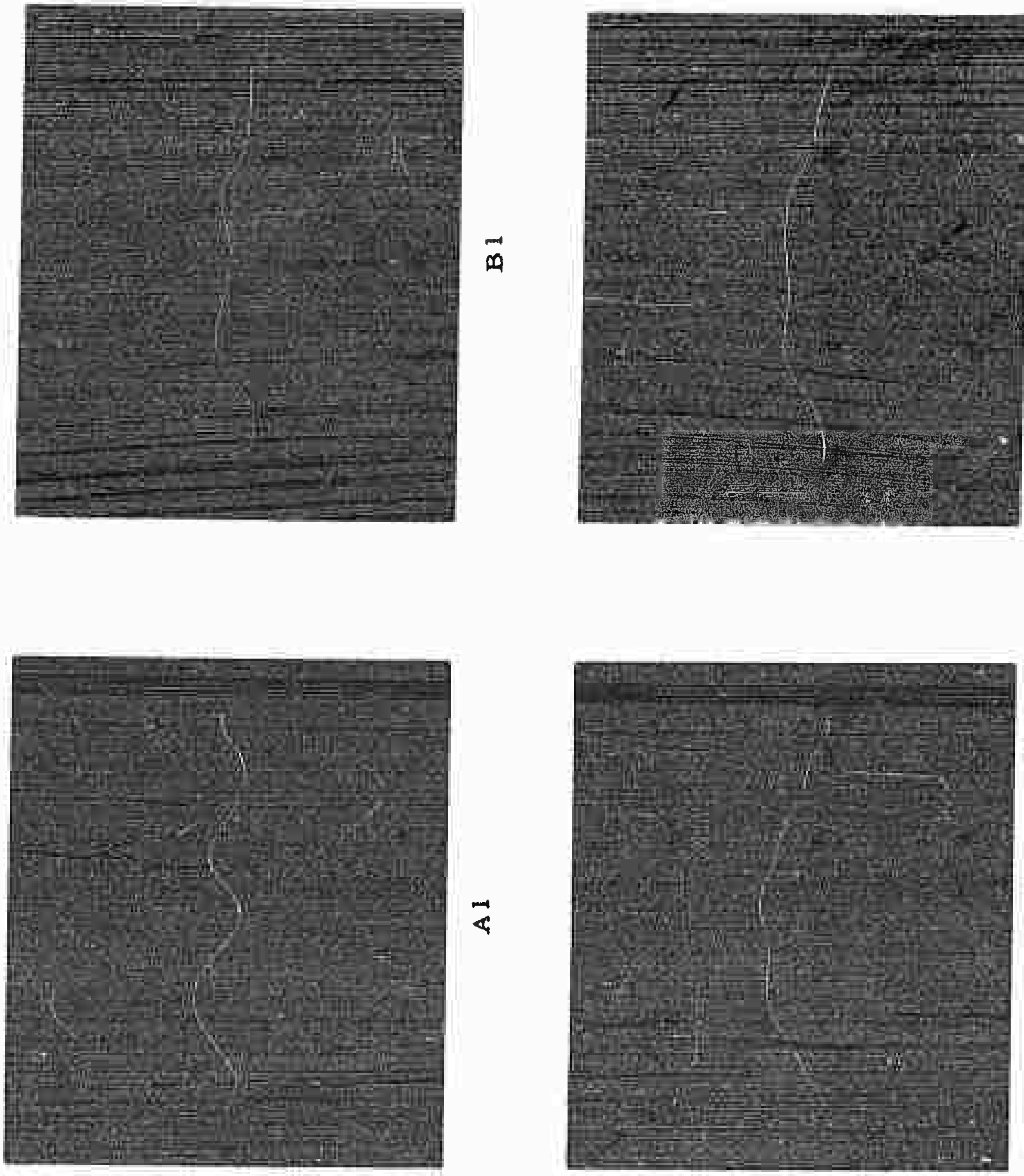


FIGURE 15 WAVE FORM PATTERNS OF HIGHLY TEMPERED OR RETEMPERED BOLTS

FINAL AND IN-PROCESS INSPECTION

Although results and progress on the bolt segregation program were most successful, it is felt that the combination of tests with surface hardness, magnetic reading, and wave form pattern is too complicated to employ as an in-process inspection method. Engineers who are experienced with the problem and have observed wave form pattern differences and resultant material properties are able to make suitable segregations but the test is not sufficiently refined nor of relative ease to specify limits and procedures which could be incorporated in a drawing or specification for general inspection.

A test method employing a combination of Rockwell C and D hardness measurements on the receiver has proven extremely reliable for estimation of core hardness. Studies are now being made to determine the reliability as regards bolt inspection. A fixture has been designed for taking hardness measurements on the bottom of the left lug area. Results will be reported upon termination of studies.

APPENDICES

A - Graphs

B - Distribution

GRAPHS

Section 1

Metallurgical Data on Bolts which Malfunctioned at Fort Benning and at "Code HG" Plant

BOLT IDENTITY	HARDNESS			MICROSTRUCTURE			CASE		REMARKS
	SURFACE Rc	CORE LUG Rc	CORE BODY Rc	FREE FERRITE	UPPER BAINITE	MARTENSITE AND LOWER BAINITE	DEPTH (INCHES)	RETAINED AUSTENITE	
CODE WH 19453	58-60	35	35-38	40-50%	2-5%	REM.	.020	100% TO .0005" 25% NEXT .004"	BOTH LUGS FRACTURED
CODE WH 19478	56-59	40.5-42	39-41	10-20%	5-10%	"	.016	NONE	
CODE WH 19391	55-58	25-27	31.5-33	50%	15-25%	"	.014-.016	100% TO .0005" 30% NEXT .004"	LEFT LUG ALMOST SEVERED.
S.A. 19656	56-57	37-38	38-42	0-5%	40-50%	"	.015-.016	50% TO .003" (VERY IRREGULAR)	TRIANGULAR PIECE BROKEN FROM ALONG EJECTOR PIN HOLE.
CODE HG 73293	54-55	40-43	38-42	0-5%	25-30%	"	.017-.018	20% TO .004"	

Section 2

Magnetic and Metallurgical Data on Bolts in Retentivity Study

BOLT IDENTITY	OPPOSING CURRENT ($-I_H$) (MA)	LUG CORE HARDNESS R_c	MICROSTRUCTURE			CASE		REMARKS
			FREE FERRITE	UPPER BAINITE	MARTENSITE AND LOWER BAINITE	DEPTH (INCHES)	RETAINED AUSTENITE	
HRT-J4	405	33-33-35-36	5-10%	30-50%	REM	.019-.020	30-0% TO .004"	
HRT-L3	390	37-38-38-39	8-12%	50-60%	"	.020-.022	TRACES OF 100% ON SURFACE.	
HRT-L4	380	32-35-35-35	3-7%	20-35%	"	.020	TRACES OF 100% ON SURFACE.	
HRT-R15	370	44.5-45-45-45.5	3-7%	5% MAX.	"	.018-.019	30-10% TO .005"	
HRT-R10	350	44-44-44.5-45	3-5%	0-5%	"	.016-.018	TRACES	
HRT-R14	360	44-44.5-45-45.5	0-3%	0-5%	"	.017-.019	10-5% ON SURFACE	
CA05-7	260	41-41-41-42	8-12%	5-10%	"	.017-.020		RETEMPERED AT 530°F.
CA05-5	265	42-42-43-43	5-10%	0-5%	"	.017-.020		RETEMPERED AT 530°F.

BOLT IDENTITY	OPPOSING CURRENT ($-I_H$) (MA)	LUG CORE HARDNESS (R_c)	MICROSTRUCTURE: FREE FERRITE	MICROSTRUCTURE: UPPER BAINITE	MICROSTRUCTURE: MARTENSITE AND LOWER BAINITE	CASE: DEPTH (INCHES)	CASE: RETAINED AUSTENITE
66118 A 36	470	41-41-42-43	5% MAX	15-25%	REM.	.022-.023	55-20% TO .003"
66118 A 1	465	41-41-41-41	3-7%	15-20%	"	.020-.022	40-15% TO .004"
66118 A 12	455	40-40-41-41	3-7%	20-30%	"	.018-.020	30-15% TO .003"
66118 A 5	450	40-40-40-41	5-10%	20-35%	"	.017-.018	60-10% TO .005"
66118 A 29	450	40-43-43-44	5-10%	15-20%	"	.022-.023	35-25% TO .003"
66118 A 31	450	37-38-38-39	5-10%	30-35%	"	.020-.021	30-10% TO .0025"
66118 A 15	445	40-40-41-41	5% MAX.	15-25%	"	.016-.017	40-15% TO .005"
66118 A 25	430	32-32-33-33	5-10%	35-50%	"	.020-.022	40-10% TO .004"
66118 A 20	425	32-35-36-36	3-7%	25-35%	"	.017-.018	45-35% TO .0025"
66118 A 7	420	35-35-37-37	3-7%	20-30%	"	.017-.019	40-15% TO .004"
66118 A 2	415	33-33-33-33	3-7%	25-45%	"	.016-.018	40-10% TO .003"
HRT Q-8	405	45-45-46-46.5	3-5%	0-5%	"	.018-.019	20% TO .002"
66118 B-3	390	39-39.5-40-41	20-30%	5-10%	"	.023-.024	TRACES
HRT Q-18	405	41-42-42.5-43	5-10%	5-15%	"	.017-.019	NONE
HRT Q-11	405	45-45-46-46.5	3-5%	0-5%	"	.016-.018	60-10% TO .003"
66118 A-1	420	40-40-40-40	7-12%	10-20%	"	.015	10-5% TO .002"
66118 F-1	440	41-41-42-42	5-10%	15-20%	"	.015-.017	100% TO .005" 20% TO .003"
66118 F-2	425	37-37-37-37	10-17%	30-45%	"	.016-.018	100% TO .0015"
66118 E-2	395	36-36-37-38	25-40%	5-10%	"	.014-.016	100% TO .0015"
66118 G-1	425	37-39-39-40	25-35%	15-25%	"	.016	100% TO .001". 20% TO .002"
66118 D-1	385	39-39-40-40.5	15-25%	5% MAX.	"	.018-.020	100% TO .0005"
66118 D-2	395	37-37-38-39	15-25%	5% MAX.	"	.016-.017	NONE
66118 H-1	375	36-36-37-37	40-50%	0-10%	"	.015-.016	TRACES
66118 H-2	370	37-38-39-39	20-25%	TRACES	"	.015-.017	NONE
HRT J-1	410	34-35-38-39	3-7%	35-45%	"	.014-.016	25-15% TO .002"
HRT J-2	410	34-34-35-36	5-12%	35-50%	"	.015-.018	35-25% TO .004"

APPENDIX A

Section 3

Metallurgical Data on Bolts in A.C. Hysteresis Loop Measurement Study

A.C. HYSTERESIS LOOP MEASUREMENTS

BOLT IDENTITY	HARDNESS			MICROSTRUCTURES			CASE		REMARKS
	SURFACE Rc	CORE LUG Rc	CORE BODY Rc	FREE FERRITE	UPPER BAINITE	MARTENSITE AND LOWER BAINITE	DEPTH	PERCENT RETAINED AUSTENITE	
#1	59-60	41	39-41	3-7	15-20	REM.	.020-.022	40-15 AT .004	
#2	58-58.5	38-39	32-40	3-7	25-45	"	.016-.018	40-10 AT .003	CRACK LUG .0025
#3	54-55	36-40	36-42	3-7	25-30	"	.017-.018	40-10 AT .003	MISMATCH IN FILLET
#4	57-59	40-41	36.5-39	3-7	20-30	"	.018-.020	35-10 AT .004	
#5	59-59.5	40-41	40-42	5-10	20-35	"	.017-.018	60-10 AT .005	CRACK .013-.014
#6	58.5-59	34-37	34-40	3-7	45-65 COARSE	"	.017-.018	20 AT .002	CRACK IN FILLET .007
#7	59-60	37	32-39.5	3-7	20-30	"	.017-.019	40-15 AT .004	CRACK .0025
#8	59-60	43-44	41.5-43.5	3-7	10-20	"	.016-.018	30-15 AT .004	GRAIN BOUNDARY CONST. TO .001
#9	59-60.5	40	42.5-44	5 MAX.	10 MAX.	"	.018-.020	25-10 AT .0025	CRACK IN FILLET .007-.008
#10	60	42-43	40-42	5 MAX	7 MAX.	"	.019-.022	60-15 AT .004	CRACK .004 MISMATCH RADIUS
#11	59-59.5	36-37	40.5-42.5	3 MAX.	35-50	"	.017-.019	15 AT .002	CRACK .004 MIS-MATCH RADIUS
#12	58-60	40-41	38-41.5	3-7	20-30	"	.018-.020	30-15 AT .003	ROUGH MACH. IN FILLET
#13	59-60	41-42	39.5-42	3-7	15-25	"	.018-.019	40-10 AT .005	CRACK .008
#14	59-60.5	37-39	35-40.5	3-7	15-25	"	.018-.019	35-25 AT .0025	
#15	59.5	41	40.5-42	5 MAX.	15-25	"	.016-.017	40-15 AT .005	MIS-MATCH IN FILLET
#16	58.5-60	40-41	40-42	3-7	15-30	"	.018-.019	30-15 AT .004	
#17	57-58	33-34	34.5-39.5	3-7	40-75	"	.015-.016	20 AT .002	
#18	59-60.5	40-41	41.5-45	5-7	15-20	"	.016-.017	30-5 AT .003	
#19									

Section 4

Metallurgical Data on Bolts in Coercive Force - Magnetic Permeability Study

A.C. HYSTERESIS LOOP MEASUREMENTS

BOLT IDENTITY	HARDNESS: SURFACE R_c	HARDNESS: CORE LUG R_c	HARDNESS: CORE BODY R_c	MICROSTRUCTURES: FREE FERRITE	MICROSTRUCTURES: UPPER BAINITE	MICROSTRUCTURES: MARTENSITE AND LOWER BAINITE	CASE: DEPTH (IN.)	CASE: PERCENT RETAINED AUSTENITE	REMARKS
BAO 3	53.5-5[illegible]	35-37	33-37.5	5-10	30-50	REM.	.019-.020	30-0 TO .004"	SEVERE PITTING IN FILLET RADIUS GRAIN BOUNDRY CONSTITUENTS TO .0005"
BAC 3 J-2	54-56	31-34	31.5-34	3-10	40-60 COARSE	"	.020	60-10 TO .004"	SEVERE PITTING IN FILLET GRAIN BOUNDRY CONSTITUENTS TO .0005"
BAC 3 U-10		31-32		5-10	40-75 COARSE TO BLOCKY	"	.020-.021	70-5 TO .005"	SEVERE DEEP PITTING IN FILLET. GRAIN BOUND. CONSTITUENTS TO .0005"
BAO 3 P-2	51.5-52.5	34	33-37	3-10	20-45 BLOCKY	"	.023	TRACES OF 100% ON SURFACES	SEVERE PITTING IN FILLET. TRACES OF GRAIN BOUNDRY CONSTITUENTS.
BAO 3 L-3	50.5-52.5	32-35	30-34	8-12	30-60 COARSE BLOCKY	"	.020-.022	TRACES (.001") OF 100% ON SURFACES	SEVERE DEEP PITTING IN FILLET. TRACES OF GRAIN BOUNDRY CONSTIT.
BAO 3 L-4	56-57	37-39	38-42.5	3-7	20-35	"	.020	TRACES OF 100% ON SURFACE	SEVERE DEEP PITTING IN FILLET. TRACES OF GRAIN BOUNDRY CONSTIT.
BAO 4 M-9		37-41		3-10	15-35	"	.021	TRACES OF 100% ON SURFACE 20-10 TO .004"	SEVERE PITTING IN FILLET. TRACES OF GRAIN BOUND. CONSTITUENTS.
CAO 5 Q-16	55.5-56	38-40	39.5-41.5	10-15	15-20	"	.018-.020	15 TO .002"	SLIGHT PITTING IN FILLET
BAO 4 P-15	54.5-55	46-47	44.5-46	3-7	5 MAX.	"	.018-.019	30-10 TO .005"	
BAC 4 M-19	55.5-57	39-44	34.5-38.5	3-10	15-30	"	.019-.021	100% TRACES ON SURFACE. LOOKS RETEMPERED. 30 TO .003"	SEVERE SURFACE PITTING.
BAO 4 R-17	55.5-56	45-47	44.5-46.5	3-7	TRACES 5%	"	.018-.020	TRACES LOOKS RETEMP.	
BAC 3 J-5	55.5-56.5	37-40	31.5-35	5-10	35-45	"	.017-.019	100% TO .0005" 30-10 TO .003"	SEVERE SURFACE PITTING IN FILLET.
BAO 4 R-10	53.5-55	46-47	44-46	3-5	TRACES 5%	"	.016-.018	TRACES LOOKS RETEMP.	
66118 F-4		40-41		5-10	25-35	"	.016-.019	100% FROM TRACES AT SURFACE TO .00025". 30-10 TO .004	SOME PITTING GRAIN BOUNDRY CONSTITUENTS TO .0005"
CAO5 Q-10	56.5-57	41-45	43-44	5-12	5-20	"	.016-.018	25-10 TO .002	SOME HEAVY PITTING IN FILLET RADIUS.
BAO3 K-3	52-54	39-41	35-36.5	3-7	15-25	"	.017-.019	TRACES OF 100% AT SURFACE.	HEAVY PITTING IN FILLET AREA.

A. C. HYSTERESIS LOOP MEASUREMENTS

BOLT IDENTITY	HARDNESS			MICROSTRUCTURES			CASE		REMARKS
	SURFACE R_c	CORE LUG MIN CONV R_c	CORE BODY R_c	FREE FERRITE	UPPER BAINITE	MARTENSITE AND LOWER BAINITE	DEPTH (IN)	PERCENT RETAINED AUSTENITE	
BAOA P-4		43-44		3-5	5-15	REM.	.019-.021	80-10 TO .004"	SEVERE PITTING IN FILLET RADIUS AND REAR LUG AREA.
BAOA M-11		43-45		3 MAX.	10-20		.017-.018	55-5 TO .008"	SEVERE PITTING IN FILLET RADIUS.
BAOA F-2		43-44		3-5	5-25		.018-.020	60-10 TO .004"	SEVERE PITTING IN FILLET RADIUS. GRAIN BOUNDARY CONSTITUENTS TO .00025".
BAOA P-14		45-46		3 MAX	TRACE TO 5		.017-.019	10-5 ON SURFACE	PITTING (AVERAGE)
BAOA N-3	56-57.5	39-41	35-39	3-5	20-40		.019-.021	65-5 TO .004"	SEVERE PITTING ON BODY SURFACE. GRAIN BOUNDARY CONSTITUENTS TO .0005".
66118 F-3		43-45		10-15	5-20		.016-.017	50-35 TO .0025"	SEVERE PITTING OVER ALL. BURST .003" BELOW SURFACE. CRACK (.012") IN FILLET RADIUS. GRAIN BOUNDARY CONSTIT. TO .0001". TRANSFORMED IN GRINDING.
SA CA3 NO. 11		35-37		3-7	15-30	"	.018-.019	70-15 TO .004"	DEEP PITS. CRACK .00075" LONG .0002" BELOW BASE OF A PIT. GRAIN BOUNDARY CONST. TO .0001".
SA CA8 NO. 22		39-40		3-7	10-25	"	.018-.020	25-10 TO .002" BACK OF LUG OVERHEATED IN GRINDING.	DEEP PITS. TRACES OF 100% RETAINED AUSTENITE. GRAIN BOUNDARY CONST TO .0005".
HRT A01 58737	53-56	33-34	32-40.5	5-12	30-60	"	.017-.018	TRACES OF 100% 40-10 TO .003"	HEAVY PITTING. GRAIN BOUNDARY CONSTITUENTS TO .0006".
HRT A01 58703	58.5-61	34-35	35-39	15-25	10-20	"	.030-.031	NONE	SEVERE PITTING. 100% DECARB. TO .001" PARTIAL DECARB. ADDITIONAL .0005"
66118 NO. 5	57-58	40-41	35.5-44.5	3-10	10-25	"	.018	TRACES OF 100% 40-15 TO .0025"	CRACK ABOVE FILLET RADIUS .008". GRAIN BOUNDARY CONSTITUENTS TO .0005"-.00075".
HRT A01 58828	60.5-62	40-43	39.5-43	5-12	10-20	"	.030-.032	NONE	SEVERE PITTING. TOTAL DECARB. TO .0015" PARTIAL DECARB. FOR ADDITIONAL .0015"
66118 NO. 7	53-56	31	32.5-38	5-15	30-70	"	.017-.018	60-10 TO .004"	CRACK .006"-.007" GRAIN BOUNDARY CONST. TO .0005".
HRT A01 57816	59-60	36-37	35-39.5	10-20	10-20	"	.031-.032	NONE	TOTAL DECARB. .00075" TO .003". PARTIAL FOR ADDITIONAL .0005".

A. C. HYSTERESIS LOOP MEASUREMENTS

BOLT IDENTITY	HARDNESS			MICROSTRUCTURES			CASE		REMARKS
	SURFACE R_C	CORE LUG KNN CONV R_C	CORE BODY R_C	FREE FERRITE	UPPER BAINITE	MARTENSITE AND LOWER BAINITE	DEPTH (IN INCHES)	PERCENT RETAINED AUSTENITE	
SA CA3 NO. 9	56-58	34-35	38-45	3-10	15-35	REM.	.018-.019	TRACES OF 100% 55-10 TO .005"	SEVERE PITTING. GRAIN BOUNDARY CONST. TO .0005"
HRT A02 BODIE	54-55	34-37	38-42	10-15	15-25	"	.017-.019	25-5 TO .004"	EXCESSIVE ALUMINUM OXIDE INCLUSIONS. LARGE GROUPS HEAVY PITTING
HRT CA05 G-8	56-57	45-47	45-46.5	3-5	5	"	.018-.019	20 TO .002"	LARGE PITTING IN FILLET. SLIGHT PITTING ON SURFACE. GRAIN BOUNDARY CONSTITUENTS TO .0005"
SA CA3 NO 7	58-59	39-41	36-39.5	5-12	15-25	"	.022-.024	60-5 TO .005"	SEVERE PITTING. OVERHEATED IN GRINDING. GRAIN BOUNDARY CONST. TO .0004
SA CA3 NO. 23	57-58	37-39	38.5-40.5	3-7	10-30	"	.018-.020	100% TO .0005" 40-10 TO .005"	SEVERE PITTING CRACK .017"-.018"
66118 B-5	58.5-59	39-41	39-41.5	20-30	5-10	"	.023-.024	TRACE (RETEMPERED)	GRAIN BOUNDARY CONST. TO .0005". HEAVY PITTING. INTERNAL CRACK IN CASE .003"
66118 NO. 8	58.5-59.5	38-39	40.5-42.5	3-7	10-25	"	.018-.019	40-10 TO .008"	CRACK IN FILLET RADIUS .010"-.011" STARTS IN GRAIN BOUNDARY CONST. GRAIN BOUNDARY CONST. TO .0005"
66118 NO. 10	55-58.5	33-35	37.5-43	5-10	25-45	"	.017-.019	100% TRACES 50-10 TO .004"	GRAIN BOUNDARY CONST TO .0004
BA04 N-4	56.5-57	40-42	35-39.5	3-5	10-25	"	.018-.020	50-10 TO .005"	SEVERELY PITTED IN FILLET RADIUS.
66118 D-3	58.5-59.5	40-42	38-41.5	15-25	5-10	"	.019-.020	NONE (DOUBLE TEMPER)	CRACKS .005" IN FILLET RADIUS. GBC TO .0005"+
SA CA3 NO 17	58.5-58.5	39-41	38.5-41.5	3-7	15-35	"	.021	45-5 TO .004"	GBC TO .0005" SEVERE PITTING ON BODY SURFACE BELOW LUG. OVERHEATED IN GRINDING.
SA CA3 NO 4	58.5-58.5	37-37	36-39	3-10	25-65	"	.018-.020	60-10 TO .005" 100% TO .00025"	CRACK .012"-.013"
66118 A-3	52.5-56	39-39	34.5-39	3-10	20-45	"	.018	TRACES OF 100% 35-5 TO .0025"	TRACES OF GBC CRACKS IN FILLET [illegible] SEVERE PITTING LUG AREA.
66118 A-4	57-57	41-42	34-42	5-25	5-10	"	.018-.019	100% TO .00025" 50-5 TO .0025"	CRACKS IN FILLET .011" & .003". SEVERE PITTING.
66118 G-3	57-58	42-45	40-45	15-35	TRACES TO 3%	"	.017-.018	100% DECREASE TO .0005". 100% RETAINED [illegible] .002"-.0005"	—
66118 G-4	56-57	36-37	38-42	3-15	25-65	"	.016-.018	30-5 TO .005" 100% .0005 TO .00015	GBC TO .0005 NUMEROUS PITS & CRACKS FILLET AREA.
66118 E-5	56-60	42-43	41.5-45.5	3-5	5-10	"	.021	45-5 TO .004"	GBC TO .0005" PITTING ON [illegible] SURFACES.

A. C. HYSTERESIS LOOP MEASUREMENTS

BOLT IDENTITY	HARDNESS			MICROSTRUCTURES			CASE		REMARKS
	SURFACE R_c	CORE LUG	CORE BODY R_c	FREE FERRITE	UPPER BAINITE	MARTENSITE AND LOWER BAINITE	DEPTH (IN INCHES)	PERCENT RETAINED AUSTENITE	
HRT CA05 Q.10	56.5-57	41-43	43-44	3-7	5-20	REM	.016-.018	30-10 TO .004"	SOME HEAVY PITTING IN FILLET AREA.
HRT CA05 Q.12	55-56.5	45-46	44-44.5	5-12	5-10	"	.016-.019	30-5 TO .0045"	SEVERE PITTING, GBC IN BASE OF MANY PITS TO .00015".
HRT CA05 Q-15	56-57	41-44	45.5-46	8-10	5-15	"	.017-.019	60-10 TO .004"	PITTING.
HRT CA05 Q.17	55-56	43-44	43-46	3-10	TRACES TO 10	"	.017-.019	20-5 TO .004"	GBC TO .0002". PITTING IN FILLET RADIUS.
HRT CA05 Q.18	55-56	41-44	41-43	5-10	5-15	"	.017-.019	NONE (RETEMPERED?)	TRACES OF GBC SOME PITTING.
HRT CA05 Q.19	55.5-56	41-43	42-43	3-7	TRACES TO 5	"	.016-.019	40-10 TO .001" (RETEMPERED?)	TWO FINE CRACKS IN FILLET RADIUS .003". SEVERE PITTING OCCASIONAL GBC TO .0002"
66118 NO A-4	52-57	41-42	34-42	5-25	5-10	"	.018-.019	100% TO .00015 20-3 TO .0023	SEVERE PITTING. CRACKS IN FILLET .041" & .003".
BA05 A.2	51.5-52.5	34-34	34-35	5-10	20-45 BLOCKY	"	.023	TRACES OF 100% ON SURFACE.	SEVERE PITTING IN FILLET RADIUS. TRACES OF G.B.C.
HRT A01 58627	54.5-56.5	33-34	32.5-33.5	3-7	30-65	"	.018-.020	45-10 TO .002	SEVERE PITTING. CRACK IN FILLET RADIUS .015".

Section 5

Magnetic and Metallurgical Data on Bolts in Wave Form Pattern Study

BOLT IDENTITY	MICROSTRUCTURE			CASE		REMARKS
	FREE FERRITE	UPPER BAINITE	MARTENSITE AND LOWER BAINITE	DEPTH (INCHES)	RETAINED AUSTENITE	
67988	5-17%	5% MAX	REM.	.019-.020	5% TO .002"	HEAVY PITTING ON BODY WALL AND RADIUS.
69216	3-10%	5-10%	"	.018-.019	10% TO .002"	HEAVY PITTING.
77533	5-12%	15-25%	"	.017-.018	TRACES	PITTING ON LUG RADIUS AND WALL.
78153	5-20%	5-15%	"	.018-.019	10% TO .002"	HEAVY PITTING ON LUG RADIUS AND WALL
75089	5-12%	5-15%	"	.018-.019	10% TO .002"	BODY WALL TRANSFORMED IN GRINDING TO .00[illegible]
69852	3-10%	5-8%	"	.015-.016	TRACES	GRAIN BOUNDARY CONSTITUENTS TO .0004". SEVERE MISMATCH IN RADIUS WITH CONSIDERABLE COLD WORK IN THIS AREA.
76002	3-10%	5-20%	"	.016-.017	TRACES	
70825	3-12%	3-15%	"	.018-.019	TRACES	
70190	3-10%	5-10%	"	.016-.018	15% TO .003"	SEVERE PITTING.
68722	5-15%	5-15%	"	.018-.019	TRACES	
71355	3-10%	5-20%	"	.018-.019	TRACES	SEVERE PITTING.
73237	5-15%	10-20%	"	.018-.019	10% TO .0015"	HEAVY PITTING ON BACK OF LUG AND RADIUS.
77109	5-10%	5-15%	"	.016-.017	15-20% TO .003"	HEAVY PITTING IN LUG RADIUS.
70400	3-5%	0-5%	"	.015-.016	5% TO .002"	HEAVY PITTING. MISMATCH IN LUG AREA.
69981	3-7%	0-5%	"	.015-.016	TRACES	FIVE MICRO CRACKS .0005" MAX. IN RADIUS AND LUG. VERY LITTLE CASE REMAINING IN RADIUS.
74387	5-10%	0-5%	"	.014-.015	10-5% TO .002"	
74823	3-7%	5-8%	"	.014-.015	TRACES	HEAVY PITTING IN LUG WALL AND RADIUS.
77188	3-10%	5-7%	"	.016-.018	15% TO .0025"	TRANSFORMATION OF BODY WALL DURING GRINDING. HEAVY PITTING IN LUG RADIUS AND BODY WALL.
76924	3-5%	0-5%	"	.018-.019	10% TO .001"	

BOLT IDENTITY	MAGNETIC READING	BASIC WAVE FORM PATTERN	SURFACE HARDNESS RANGE Rc	CORE HARDNESS RANGE Rc	MICROSTRUCTURE			CASE	
					FREE FERRITE	UPPER BAINITE	MARTENSITE AND LOWER BAINITE	DEPTH (INCHES)	RETAINED AUSTENITE
72246	-10	3	52-56	43.5-46	3-8%	3-7%	REM.	.019-.020	TRACES
76342	-9	3	58-59.5	42-44	3-10%	0-5%	"	.018-.019	0-5%
72572	-15	3	58-58.5	38-43	5-10%	3-7%	"	.016-.017	TRACES
70944	-20	3	57-59	45-46					
72086	-20	3	59	42-43					
74845	-30	3	57-58	43-44.5	3-5%	0-5%	"	.018-.020	60% TO .003"
75326	-13	3	58-58.5	43-44.5	5-10%	0-5%	"	.017-.018	TRACES
72200	+7	3	58-60	43-44.5	3-10%	5-10%	"	.019-.021	5% TO .0015"
69364	-5	2	58	39.5-42	3-8%	3-8%	"	.016-.017	TRACES
58937	-2	2	59-59.5	40.5-42	3-8%	3-7%	"	.018-.020	TRACES
70680	-4	2	59-60	40.5-42.5	3-7%	0-3%	"	.020-.021	10% TO .0015"
66538	-10	2	57-58	41-42.5	3-8%	5-8%	"	.019-.020	5% TO .001"
69882	+22	2	57.5-58.5	39-42	3-10%	5-12%	"	.015-.017	TRACES
70497	+6	2	58	40-41.5	3-8%	3-12%	"	.018-.019	TRACES
70942	0	2	57.5-59	39.5-42	3-10%	5-8%	"	.017-.018	TRACES
69191	-2	2	57-58	41.5-43	3-8%	3-8%	"	.015-.016	10% TO .001"
69627	-5	2	57.5-58	40-44	3-10%	5-10%	"	.018-.019	TRACES
75268	-10	2	54-56.5	38.5-42	5-12%	5-15%	"	.016-.018	5% TO .001"
69210	-17	2	55-56	42-43	3-8%	3-7%	"	.018-.019	NONE
69625	-20	2	56	38.5-41.5	5-15%	5-12%	"	.019-.020	20% TO .002"
69394	-20	2	56-56.5	39.5-42.5	3-8%	3-8%	"	.015-.017	TRACES
68969	+7	2	58-60	42-43	3-8%	3-5%	"	.019-.021	TRACES
69732	-6	2	58.5-59	38-42	5-12%	5-15%	"	.018-.020	TRACES
71153	-12	2	57-58	34.5-40.5	3-8%	5-20%	"	.018-.020	10-5% TO .001"

Section 6

Metallurgical Data on Bolts in Oscillogram Study

BOLT IDENTITY	LUG CORE HARDNESS Rc	MICROSTRUCTURE			CORE		REMARKS
		FREE FERRITE	UPPER BAINITE	MARTENSITE AND LOWER BAINITE	DEPTH (INCHES)	RETAINED AUSTENITE	
BA04 75706	37-39	5-10%	25-40%	REM	.018-.020		HEAVY PITTING.
BA04 75285	43-44	0-3%	0-3%	"	.016-.017	5% TO .005"	
BA04 84919	35-38	3-7%	30-60%	"	.018-.019		HIGHLY RETEMPERED.
BA04 74678	38-39	3-5%	15-35%	"	.016-.018	5-3% TO .002"	
BA04 77984	36-39	3-7%	15-40%	"	.017-.018	5% TO .001"	CASE IN FILLET .007" MAX.
BA04 72157	42-43	0-3%	3-7%	"	.017-.019		GRAIN BOUNDARY CONSTITUENTS TO .0005".
A03 75794	43-45	0-3%	0-2%	"	.019-.020	30-25% TO .002"	
A03 73765	41-43	0-5%	0-5%	"	.017-.018	NONE	
A03 74066	42-44	3-5%	0-3%	"	.018-.020	45-35% TO .002"	DEEP PITTING.
A02 57665	40-41	3-8%	3-15%	"	.017-.019	TRACES	
A03 72127	43-44	3-8%	0-3%	"	.017-.018	60-40% TO .002"	SEVERELY PITTED.
A02 57809	42-43	3-12%	0-5%	"	.018-.020		HIGHLY RETEMPERED-DEEP PITTING.
A03 86954	40-42	3-12%	0-8%	"	.018-.021		HIGHLY RETEMPERED.
A03 74623	39-41	8-17%	0-5%	"	.019-.020	NONE	
A03 77737	41-43	8-10%	0-3%	"	.017-.019	NONE	
A03 68008	34-37	10-17%	3-12%	"	.017-.019	80% TO .002"	
A03 70737	33-34	12-22%	5-10%	"	.017-.018	TRACES	
A03 85147	38-41	8-20%	0-5%	"	.017-.018		HIGHLY RETEMPERED.
A03 75329	33-35	8-25%	5-15%	"	.017-.018	TRACES	DEEP PITTING.
A02 74128	35-37	3-10%	3-12%	"	.016-.017		
A03 74984	33-34	15-25%	10-20%	"	.017-.018	40-30% TO .0025"	HIGHLY RETEMPERED.
A03 76487	34-37	10-20%	10-15%	"	.018-.019	25% TO .002"	
BA04 72157	41-43	0-3%	3-7%	"	.017-.019	NONE	GRAIN BOUNDARY CONSTITUENTS TO .0005".
A03 74127	35-37	5-10%	5-10%	"	.018-.020	40% TO .0025"	DEEP PITTING.

BOLT IDENTITY	LUG CORE HARDNESS Rc	MICROSTRUCTURE			CORE		REMARKS
		FREE FERRITE	UPPER BAINITE	MARTENSITE AND LOWER BAINITE	DEPTH (INCHES)	RETAINED AUSTENITE	
A03 67282	33-34	12-22%	12-22%	REM.	.017-.018	TRACES	RETEMPERED.
A03 76750	34-36	17-25%	7-15%	"	.017-.018	TRACES	RETEMPERED.
A05 78204	40-41	7-17%	3-8%	"	.018-.019	NONE	
A03 84563	41-43	3-10%	0-5%	"	.020-.021	TRACES	RETEMPERED.
A02 72050	41-43	3-10%	0-5%	"	.018-.019	30-40% TO .005"	HEAVY PITTING.
A02 65518	42-43	3-5%	5-8%	"	.018-.019	25-10% TO .002"	SEVERELY PITTED.
A03 75854	34-35	12-22%	5-10%	"	.014-.016	TRACES	
A03 C	38-40	3-7%	3-15%	"	.018-.019	TRACES	
A03 71362	36-38	5-12%	5-12%	"	.018-.019	40-30% TO .005"	HEAVY PITTING.
A03 68763	34-35	7-15%	10-20%	"	.018-.019	40-30% TO .005"	
A03 87339	41-43	3-5%	3-5%	"	.018-.020	TRACES	RETEMPERED - MISMATCH IN FILLET.
A03 86750	42-43	3-5%	3-8%	"	.015-.016	TRACES	HIGHLY RETEMPERED.
BA03 84696	31-34	5-8%	40-70%	"	.018-.020		HIGHLY RETEMPERED.
BA03 C-6	33-34	5-8%	35-55%	"	.018-.019		HIGHLY RETEMPERED.
BA04 302	35-37	0-5%	15-25%	"	.018-.019		HIGHLY RETEMPERED.
BA04 C-3	41-42	0-3%	3-5%	"	.016-.018		HIGHLY RETEMPERED.
BA03 86920	34-35	3-7%	60-75%	"	.018-.020		HIGHLY RETEMPERED.
BA04 T-2	40-42	3-5%	3-5%	"	.017-.018		HIGHLY RETEMPERED.
BA03 86406	37-39	3-7%	3-7%	"	.017-.018		HIGHLY RETEMPERED.
BA03 77238	37-39	5-10%	10-15%	"	.017-.018		HIGHLY RETEMPERED.
BA04 T-1	46-47	0-1%	0-1%	"	.018-.020		HIGHLY RETEMPERED.
BA04 84948	34-36	8-10%	40-60%	"	.016-.017		HIGHLY RETEMPERED.
BA03 84967	33-34	5-15%	35-75%	"	.018-.019		HIGHLY RETEMPERED.
BA03 74973	37-41	3-8%	5-15%	"	.018-.019		HEAVY PITTING.

BOLT IDENTITY	CORE HARDNESS Rc	MICROSTRUCTURE FREE FERRITE	UPPER BAINITE	MARTENSITE AND LOWER BAINITE	CASE DEPTH (INCHES)	RETAINED AUSTENITE	REMARKS
A03 77071	41-43	3-7%	3-5%	REM.	.014-.016	NONE	
A03 75061	39-42	3-10%	5-10%	"	.019-.020	TRACES	OVERHEATED IN GRINDING BODY WALL
A02 65722	41-42	3-12%	3-5%	"	.017-.018	5% TO .001"	GRAIN BOUNDARY CONSTITUENTS TO .0015"
A02 69039	36-38	10-22%	5-15%	"	.018-.020	TRACES	HEAVY PITTING.
A03 79620	39-41	5-10%	3-8%	"	.018-.020	15% TO .0015"	RETEMPERED.
A03 72876	38-39	5-12%	3-8%	"	.018-.020	30-20% TO .003"	HEAVY PITTING IN BODY WALL.
A03 81179	32-35	10-22%	5-20%	"	.019-.021	35-25% TO .003"	HEAVY PITTING.
A03 69689	34-37	12-25%	5-10%	"	.017-.019	45-35% TO .002"	OVERHEATED IN RADIUS AND BACK OF LUG TO A DEPTH OF .007-.008".
A03 76138	32-34	10-22%	5-15%	"	.017-.019	TRACES TO 5%	
A03 74516	34-36	5-20%	10-20%	"	.018-.020	TRACE	DEEP PITS.
A02 70705	37-41	5-15%	5-10%	"	.018-.020		TRANSFORMED IN GRINDING OR CUTTING OFF.
A03 69481	37-41	5-17%	5-10%	"	.016-.017		TRANSFORMED IN GRINDING OR CUTTING OFF.
A03 70085	33-37	10-22%	5-15%	"	.017-.018		TRANSFORMED IN GRINDING OR CUTTING OFF.
A02 71557	40-43	5-10%	5-10%	"	.016-.017	15-10% TO .003"	
A03 70713	38-42	5-10%	0-5%	"	.018-.019		
A03 66772	34-36	15-25%	0-5%	"	.017-.018		MODERATE TO HEAVY PITTING.
A02 71117	41-44	3-8%	0-5%	"	.018-.020		
A03 66011	32-34	10-30%	5-15%	"	.017-.018	10-5% TO .005"	HIGHLY TEMPERED.
A02 77643	37-38	7-15%	5-15%	"	.020-.022	TRACES	
A03 76416	32-33	7-35%	5-10%	"	.018-.019	5% TO .003	DEEP PITS - HIGHLY TEMPERED.
A02 71381	37-39	5-15%	10-20%	"	.018-.020	NONE	HEAVY PITTING.
A03 71091	34-37	10-20%	15-20%	"	.018-.019	NONE	GRAIN BOUNDARY CONSTITUENTS TO .003".
A03 76273	43-44	8-10%	0-5%	"	.017-.018	NONE	RETEMPERED.
A02 74664	39-40	5-17%	5-15%	"	.016-.017	NONE	RETEMPERED.

Section 7

Impact and Metallurgical Data on Bolts on Impact Test Study

BOLT IDENTITY	BLOWS TO RUPTURE 30 FT.LBS./BLOW 20 LB. WT.	MAGNETIC READING	PATTERN	HARDNESS		MICROSTRUCTURE			CASE	
				SURFACE Rc	ADJACENT LUG CORE Rc	FREE FERRITE	UPPER BAINITE	MARTENSITE AND LOWER BAINITE	DEPTH (INCHES)	RETAINED AUSTENITE
A02 63697	1	-15	3	56.5-58.5	44-45	3-8%	3-5%	REM.	.017-.019	10% TO .003".
A03 75243	1	-17	3	56.5-58.5	43-44	2-8%	3-8%	"	.019-.021	TRACES TO 5%.
A03 76641	1.	0	3	55-59	43-45	3% MAX.	3% MAX.	"	.018-.020	5% TO .002".
A02 74458	1	-15	2	57-60	41-43	3-10%	5-12%	"	.016-.017	5% TO .003"
A03 73539	1	-40	1	57.5	41-42	3-8%	5-10%	"	.020-.021	10% TO .002".
A02 67468	2	-17	2	58.5-59.5	42-43	5-12%	5-20%	"	.020-.021	TRACES
A03 68542	2	-7	3	58	45-46	3-5%	3-5%	"	.017-.018	NONE
A02 69418	2	-8	2	58-59	36-41	10-20%	8-12%	"	.015-.016	TRACES
A02 77643	2	-11	2	59	39-40	7-15%	5-15%	"	.020-.022	TRACE
A02 67021	3	-23	2	56-58	39-40	5-15%	5-15%	"	.017-.019	TRACES
A03 75033	3	-30	1	55.5-58	37-38	5-15%	10-20%	"	.015-.017	TRACES
A03 15	3 INC.	-12	2	58-59.5	38-40	5-15%	12-22%	"	.019-.021	TRACE
A03 71632	4	-10	3	56-58.5	44-45	3-5%	3-5%	"	.017-.019	10-5% TO .002".
A02 67254	4	-12	3	57-59.5	42	3-7%	3-7%	"	.018-.019	5% TO .002".
A03 73895	6 INC.	-25	2 FERRITE	55.5-57	39-40	10-25%	5-15%	"	.018-.019	15-10% TO .002".
A03 70085	6 INC.	-22	2 FERRITE	56.5-57.5	38-39	15-20%	15-20%	"	.017-.018	TRACE
A02 71116	6	-10	3	57-58.5	43-44	3-7%	3-7%	"	.016-.017	10-5% TO .002".
A02 69089	6	-8	2	58-59	41-43	3-12%	3-12%	"	.016-.017	10% TO .0015".
A02 71381	6	-13	2	56-57	41-42	5-15%	10-20%	"	.018-.020	NONE
A03 75852	10 INC.	-42	2 FERRITE	56-57.5	38-39	5-20%	5-20%	"	.018-.020	NONE
A02 68725	11	-33	2 FERRITE	57-59	40	8-20%	5-15%	"	.017-.019	10-5% TO .005".
A03 66772	12 INC.	-40	2 FERRITE	55.5-58.5	38-39	5-15%	15-35%	"	.017-.019	NONE
A03 69481	14	-15	2 FERRITE	53-55.5		10-20%	8-12%	"	.015-.016	TRACES
A03 71091	14 INC.	-3	2 FERRITE	58.5-60.5	35-38	10-20%	15-20%	"	.018-.019	NONE
A03 76993	20 INC.	-5	2 FERRITE	57-58	40-41	10-15% VERY FINE	10-15% VERY FINE	"	.017-.018	(PROEUTECTOID CEMENTITE ON SURFACE TO .005")

Section 8

Impact and Metallurgical Data on
Tempered Bolts in Impact Test Study

BOLT IDENTITY	PATTERN	BLOWS TO RUPTURE 30 FT. LBS./BLOW 20 LB. HAMMER	HARDNESS SURFACE Rc	HARDNESS CORE LUG Rc	MICROSTRUCTURE FREE FERRITE	MICROSTRUCTURE UPPER BAINITE	MICROSTRUCTURE *MARTENSITE AND LOWER BAINITE	CASE DEPTH (INCHES)	CASE RETAINED AUSTENITE
84771	D-1	1	55-57	39-40	5-17%	5-15%	REM.	.018-.020	5% TO .002".
85359	C-1	1	57-58	41-43	3-8%	3-8%	"	.018-.019	5% TO .002".
86053	C-1	1	57-58	41-43	5-7%	5-7%	"	.018-.020	15-10% TO .002".
78759	C-1	1	56-57.5	44-45	3-5%	0-5%	"	.020-.022	TRACES.
84749	D-1	1	58.5-59.5	41-42	5-12%	5-10%	"	.018-.019	NONE
83597	B-1	1	53-54	42-43	3-7%	0-5%	"	.014-.016	NONE
78601	C-1	1	56-57	43-44	3-5%	3-5%	"	.017-.018	NONE
88126	D-1	2	56.5-58	41-42	5-10%	5-10%	"	.019	NONE
89061	C-1	2	58-58.5	40-42	5-10%	3-10%	"	.023-.024	10% TO .003".
88870	D-1	3	58-59	42-43	3-5%	3-5%	"	.017-.018	10-5% TO .002".
85138	D-1	4	56-57.5	40-42	7-10%	5-15%	"	.017-.018	5% TO .002".
86110	B-1	5	55-59	39-41	3-7%	0-10%	"	.016-.018	TRACES
86596	A-1	8	46-49	38-39	10-20%	10-15%	"	.012-.013	NONE
89165	B-1	16	53-55.5	40-42	3-7%	3-10%	"	.020-.021	NONE
86404	A-1	17	49-50	35-39	5-15%	5-15%	"	.013-.015	NONE
86307	A-1	20	50-51	36-38	15-25%	10-15%	"	.014-.015	NONE
85944	B-1	22	54-56	42-43	3-5%	3-5%	"	.017-.018	NONE
84668	B-1	35	51.5-53	40-42	3-10%	3-6%	"	.016-.017	NONE
84492	A-1	79	52-55	39-41	10-22%	10-12%	"	.012-.014	NONE
86000	A-1	83	49-51	36.5-39	10-20%	10-20%	"	.013-.015	NONE

Section 9

Impact and Metallurgical Data on Bolts in Impact Cold Test Study

BOLT IDENTITY	FRACTURE HEIGHT 10 LB. HAMMER (INCHES)	SURFACE HARDNESS Rc	LUG CORE HARDNESS Rc	MICROSTRUCTURE			CASE	
				FREE FERRITE	UPPER BAINITE	MARTENSITE AND LOWER BAINITE	DEPTH (INCHES)	RETAINED AUSTENITE
84563	14	56-58	41-44	3-10%	0-5%	REM.	.020-.021	TRACES
BA04 F2	15	56-57	41-42	3-5%	3-5%	"	.017-.018	TRACES
BA03 C-2	15	52-55.5	35-36	8-12%	65-75%	"	.015-.016	TRACES
87339	15	56.5-57	41-43.5	3-5%	3-5%	"	.018-.020	TRACES
BA04 302	17	56-57.5	33-37	0-5%	15-25%	"	.018-.019	TRACES
78204	17	55-59	42.5-44	7-10%	3-8%	"	.018-.019	NONE
BA04 T-1	18	54-58	45.5-47	1% MAX.	1% MAX.	"	.018-.020	TRACES
76273	18	56.5-57.5	43-45	8-10%	0-3%	"	.017-.018	NONE
73200	18	56.5-59.5	41.5-44	3-7%	0-5%	"	.019-.021	TRACES
84948	18	55.5-57	34-36	8-10%	40-60%	"	.016-.017	TRACES
74664	19		36-38	5-17%	5-15%	"	.016-.017	NONE
77797	19	57-58	41-42	8-12%	0-3%	"	.017-.019	NONE
A03 304	19	58-59	37-40	5-12%	3-10%	"	.018-.019	TRACES
A02 308	20	57.5-58.5	40-41	3-8%	3-8%	"	.017-.019	50-25% TO .003"
A03 310	20	57-58.5	41-42	3-5%	3-5%	"	.018-.019	40-30% TO .002"
74623	20	56.5-58.5	39-41	8-17%	0-5%	"	.019-.020	NONE

BOLT IDENTITY	FRACTURE HEIGHT 10 LB. HAMMER (INCHES)	SURFACE HARDNESS Rc	LUG CORE HARDNESS Rc	MICROSTRUCTURE			CASE	
				FREE FERRITE	UPPER BAINITE	MARTENSITE AND LOWER BAINITE	DEPTH (INCHES)	RETAINED AUSTENITE
A03 306	21	57-57.5	41-43	5-10%	3-5%	REM.	.018-.020	5% TO .002"
A03 307	21	47-48.5	43-45	3-7%	3-7%	"	.017-.018	10% TO .002"
A03 309	21	56-59.5	42-44	3-5%	3-5%	"	.018-.020	
A03 F-3	21	56.5-57.5	33-37	10-22%	3-10%	"	.016-.018	TRACES
A03 F-2	22	52.5-54.5	35-37	10-17%	3-10%	"	.018-.020	TRACES
A03 F-5	22	56-57.5	35-39	10-15%	3-7%	"	.018-.019	TRACES
A03 C-1	23	54.5-57	38-40	3-7%	3-15%	"	.018-.019	TRACES
75329	23	55.5-57	35-39	8-25%	5-15%	"	.017-.018	TRACES
65518	23	59.5-60.5	42-44	0-3%	0-3%	"	.018-.019	TRACES
A03 301	25	55.5-57.5	35-39	5-17%	3-5%	"	.018-.019	TRACES
A03 303	25	56.5-58.5	35-39	10-17%	5-10%	"	.017-.019	50-20% TO .002"
A03 C-4	25	56.5-58	39-42	3-5%	3-5%	"	.017-.018	
72127	25	60.5-61	43-44	3-8%	0-3%	"	.017-.018	NONE
70737	30	56-57.5	32-34	12-22%	5-10%	"	.017-.018	TRACES
68008	30		33-37	10-17%	3-12%	"	.017-.019	TRACES
85147	40		38-41	8-20%	0-5%	"	.017-.018	NONE

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Springfield Armory, Springfield, Mass.

PROPERTIES AND METHODS OF NONDESTRUCTIVE TESTING OF BOLTS FOR 7.62MM M14 RIFLES, by R. B. Korytoski, H. P. Hatch, and E. H. Abbe, Tech Rpt SA-TR19-1507, 4 Jan 62, 64 pp incl tables and illus, IPM, Proj Title Nondestructive Testing, OMS Code 4010.25.0005.4.01, Industrial Production Engineering Project.

UNCLASSIFIED REPORT

Studies were made to develop adequate inspection methods of evaluating properties of material used in the fabrication of the 7.62mm M14 bolts, and to determine the feasibility of using the developed method for final and in-process inspection. These studies included (1) investigation of bolt malfunction, (2) nondestructive tests re magnetic permeability comparisons, measurements of basic magnetic properties, oscilloscope wave form pattern studies, hardness investigations, (3) bolt segregation tests, (4) simulated impact tests, and (5) application to final and in-process inspection. A test method combining Rockwell C surface hardness, magnetic permeability readings, and oscilloscope wave form patterns was developed to evaluate properties of material used in the 7.62mm M14 bolt. The combination test method was found to be too complicated to specify as a final or in-process inspection method. A magnetic comparison method similar to that employed in the segregation program could be used as a means to determine uniformity of components within individual heat lots. Procedures are discussed and results given. It was recommended that the investigation program be continued.

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3. Electromagnetic test methods
4. Processes and processing

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